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INDEPENDENT PEER REVIEW PANEL FINAL REPORT ON:

Predicted Changes in Hydrodynamics, Sediment Transport, Water Quality, and Aquatic Biotic Communities Associated with SFO Runway Reconfiguration Alternative BX-6, A3, and BX-R

Prepared for the Proposed Runway Reconfiguration at
San Francisco International Airport

REPORT OF THE INDEPENDENT SCIENTIFIC PEER REVIEW PANEL

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The Independent Scientific Peer Review Panel on Environmental Studies Conducted for Proposed New Runways at San Francisco International Airport was supported and managed by the National Oceanic and Atmospheric Administration at the request of the San Francisco Bay Conservation and Development Commission and the other federal, state, and local regulatory agencies that would have reviewed new runway construction permits, joined by the Federal Aviation Administration, the City of San Francisco, and the Airport itself. The articles, analyses, statements, and opinions contained herein reflect only those of the Panel participants and do not necessarily reflect the views of NOAA or the Department of Commerce.

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I. Introduction and Executive Summary

In 1999, San Francisco International Airport (SFO) proposed a "runway reconfiguration" project that would have built new runways, taxiways, and other airport infrastructure in San Francisco Bay. Designed to reduce weather-related delays and to accommodate new larger aircraft now under development, several of the options for new runways would have involved massive dredging and filling operations to build the new runways and would have involved other activities that would have permanently altered Bay systems and resources. The proposed project, had it been built, would have constituted one of the largest Bay fill projects ever.

The "Independent Scientific Peer Review Panel on Environmental Studies Conducted For Proposed New Runways At San Francisco International Airport" was established to help assure the public, regulatory agencies, and project sponsors alike that the science and technical studies the Federal Aviation Administration (FAA) and SFO commissioned to help prepare environmental impact documents were appropriate and executed properly. Between May 2001 and June 2003, the NOAA Panel—known as "NOAA Science Panel II"—carried out an independent peer review of these studies. In conducting an independent scientific peer review, the Panel evaluated various drafts of the study documents for scientific merit and completeness. This document is NOAA Science Panel II's final report and, taken together with the comments provided during the review, is the Panel's peer review evaluation of "Predicted Changes in Hydrodynamics, Sediment Transport, Water Quality, and Aquatic Biotic Communities Associated with SFO Runway Reconfiguration Alternatives BX-6, A-3, and BX-R."

In April 2003, SFO canceled the project, citing the effects of the September 2001 terrorist attacks on air travel and other factors that resulted in reduced air traffic and the need for the new runways. Fortunately, the city of San Francisco and SFO decided to complete these technical studies—studies that are an important contribution to our understanding of San Francisco Bay and its natural systems.

Science Panel II followed the first NOAA-convened Independent Scientific Panel on New Runways in San Francisco Bay that met in October 1999. The first Panel (called "NOAA Science Panel I") identified key environmental issues and questions for potential runway construction in the Bay and recommended an independent peer review process for any technical and scientific studies conducted in connection with new runway construction.

Both NOAA Panels were formed at the request of the San Francisco Bay Conservation and Development Commission (BCDC) and other federal, state, and local regulatory agencies that would have reviewed SFO construction permits. For NOAA Science Panel II, SFO, the FAA, and the city of San Francisco joined the regulatory agencies in asking NOAA to implement the first Panel's recommendation for peer review. NOAA Science Panel II, however, operated independently of SFO, the FAA, and the regulatory agencies.

The entire Panel met with the Runway Reconfiguration Project Management Team (SFO, the San Francsico Office of Environmental Review, the FAA, and URS, the Airport consultants) on six occasions. At other times, different subsets of the Panel met with URS scientists to address issues about scientific approach and protocols. And the chair and Panel staff met with the Project Team periodically to review Panel comments, the consultant's responses to those comments, and to address process and operation issues. In short, in conducting an independent scientific peer review, the Panel frequently interacted with the consultants and other members of the Project Team. These interactions and the Project Team's willingness to respond to Panel recommendations led to what we believe was a significant evolution of the scientific and technical studies during the peer review process. This evolution included an increase in trust between the Project Team scientists and the Panel members, an increase in the Project Team's reliance on the Science Panel for direction and guidance, and an increase in the

Project Team's willingness to incorporate additional work—sometimes at significant cost of time and money—recommended by the Panel. The result is a final study document that is more complete and substantially improved over what would have been the case had the Panel not been involved.

It is important to note that the Project Team reviewed only a subset of the many technical reports that would have been prepared for a project of this magnitude. Of these, NOAA Science Panel II reviewed only the studies then in preparation that were within NOAA's mission and programmatic areas of interest. Studies that were planned for the future—including investigations of air quality, human health impacts, wetlands, noise, transportation, economic impacts, and others—were canceled along with the runway project itself. Finally, Panel II did not address or comment on any potential mitigation under discussion to offset construction or operations impacts of the proposed runways.

Whether the environmental impacts these studies predict are acceptable, whether the runways should or should not be built at some point in the future, or what mitigation might be appropriate to offset the environmental impacts from runway construction were not decisions for the Panel to make. Those decisions are for the public to decide through the regulatory and public decision- making process.

Panel Members

The Panel Chair, Dr. Jerry Schubel, and NOAA staff selected Panelists based on areas of expertise and experience in the Bay. Potential Panelists were also screened for conflicts of interest. Panelists include active and retired scientists from federal agencies and universities. The Panelists are:

Chair

Jerry Schubel (Coastal Oceanography)
President and CEO, Aquarium of the Pacific, Long Beach. Former Provost and Dean of Marine Sciences, State University of New York, Stony Brook

Panelists

Sarah G. Allen (Marine Mammals)
Senior Scientist, National Park Service,
Point Reyes National Seashore

John Callaway (Wetland Ecology)
Assistant Professor of Environmental Science,
University of San Francisco

James E. Cloern (Ecology)
Senior Research Scientist, U.S. Geological Survey

A. Russell Flegal (Water Quality)
Professor, Environmental Toxicology
University of California at Santa Cruz

Jerry Galt (Hydrology/Modeling)
Office of Response and Restoration,
Hazardous Materials Response Division,
National Ocean Service, NOAA, retired

Janet Tashjian Hanson (Birds)
Executive Director,
San Francisco Bay Bird Observatory

Edmund (Ted) Hobson (Fish)
Retired, Chief Coastal Communities Branch,
National Marine Fisheries Service, NOAA

Herman Karl (Sediments)
Research Scientist, U.S. Geological Survey

Diane Kopec (Marine Mammals)
Biological Sciences, University of Maine

Ed Long (Sediment Toxicity)
President, ERL Environmental and Scientist,
National Ocean Service, NOAA, retired

Frederic H. Nichols (Benthos)
Research Oceanographer,
U.S. Geological Survey, retired

Gerry Orlob (Hydrology)
Professor Emeritus, Civil & Environmental
Engineering,
University of California at Davis

Thomas (Zack) Powell (Biology)
Professor, Department of Integrative Biology
University of California at Berkeley

John Stephens (Fish)
Professor emeritus, Occidental College and
Executive Director, Vantuna Research Group

David Schoellhamer (Hydrology/Sedimentation)
Research Hydrologist, U.S. Geological Survey

Bruce Thompson (Water Quality)
Senior Scientist, San Francisco Estuary Institute

Panel Staff

David McKinnie, Staff Director
NOAA, National Ocean Service, Office of Response and Restoration

CAPT Tom Richards (NOAA ret.), Program Coordinator
NOAA, National Ocean Service, Office of Response and Restoration

CDR Steve Thompson, Local Coordinator
NOAA, National Ocean Service, Office of Response and Restoration

Jennifer Johnson, ORISE Fellow
NOAA, National Ocean Service, Office of Response and Restoration

The Panel met to discuss each major draft of the studies provided it for review and prepared written comments to the Project Team. Often, the Project Team prepared detailed written responses to document how the Panel's comments were addressed. All of the Panel's written comments and the Project Team's responses are included as part of the appendix to this report. Much of this final report is drawn from those written comments.

In conducting its review, the Panel used a number of key questions to drive its assessment of the scientific and technical drafts. Those questions and the Panel's summary responses to them follow.

Summary Assessment

- Did the Airport's consultants ask the right scientific questions about the proposed project's potential environmental impacts on San Francisco Bay? Were the scientific and technical studies to address these questions designed and conducted properly?

  It is the Panel's general view that for the studies it reviewed, the consultants asked the right scientific questions about the proposed project's potential impacts on the Bay. It is important to note, however, that the studies the Panel reviewed were only a subset of the technical and scientific studies required to assess impacts completely or to develop an Environmental Impact Statement or Environmental Impact Review.

  It is the consensus of the Panel that the consultants conducted the scientific and technical studies correctly with the information and resources available at the time. As is inevitable in a study of this magnitude, Panel members and the consultants disagreed in some areas, but these disagreements do not undermine the overall quality of the studies. More detail is provided in this report, and in the Panel comments that are included in the appendix.

- Are the conclusions the consultants reached in these studies supported by the data collected, information generated, and analyses performed? In other words, are these conclusions scientifically defensible?

  The Panel's consensus view is that the data and analyses support the conclusions the consultants reached within the current state of knowledge.

- What level of uncertainty is inherent in the projected environmental impacts of the proposed runway configurations given the scope of the task and the limitations of science?

  Some level of uncertainty is inherent in any scientific endeavor. The consultants took measures to reduce the level of uncertainty in many cases. However, to the extent that certain studies were not completed—such as a full assessment of the potential effects of the project on the spring bloom—uncertainty remains that might be reduced through further study and assessments.

- What additional studies, if any, are required to evaluate as completely as possible the environmental impacts of the proposed project—during and subsequent to construction—within the context of the scope of the technical studies?

  The Panel identified a number of areas where additional work would help make the assessment of potential effects more complete. Not all of these areas of additional work fall within the purview of studies for Environmental Impact Statements or Reviews. These areas are detailed in the final report. The most significant include additional work on primary productivity and a range of monitoring activities. Another area where additional research would be appropriate is in assessing construction noise impacts on various populations of important resident and transient species, particularly fish and marine mammals.

The Value of Independent Peer Review

In reviewing and commenting on study drafts the SFO consultants prepared, the Panel requested significant changes to the normal approach to preparing technical and scientific documents for environmental review purposes, including additional data collection, analyses, descriptions, comparisons, and overviews in asking the driving questions above. It is to the credit of the FAA, SFO, the City of San Francisco, and URS that they were willing to make these changes. The Panel hopes that at least two major public benefits have accrued from the peer review process:

- The public, regulatory agencies, and project sponsors have assurance that the work conducted meets accepted scientific standards so that any future public discussion of whether new runways should be built can focus on whether projected impacts are acceptable to society and other issues of public policy—not on the quality or credibility of the scientific studies, and;
- The studies represent perhaps the most complete compendium of scientific information assembled about the Bay. They will be of great value to anyone who cares about the Bay and how it works whether or not new runways are built in the future. It is unlikely these studies would be available to the public without the commitment of all of the parties to the success of the peer review process—including SFO, the consultants, the city of San Francisco, the San Francisco Board of Supervisors, the Bay Conservation and Development Commission, and the other regulatory agencies.

II. Description of the NOAA Panel Process

Background: NOAA Panel I

In 1999, San Francisco International Airport (SFO) proposed to build new runways out into San Francisco Bay. The new runways were proposed to reduce air traffic congestion and passenger delays, increase safety by allowing aircraft to approach the Airport with a greater separation between them, and allow the Airport to handle the next generation Very Large Aircraft (VLA). The project would have been the largest construction project in the Bay for over 50 years and involved a dredging and filling operation that could have filled up to two square miles of the Bay.

Given the scale and scope of both the proposed project and its potential environmental impacts, the Bay Conservation and Development Commission (BCDC), the state agency charged with regulating fill in San Francisco Bay and with other coastal zone management responsibilities, approached NOAA to request assistance in reviewing the proposal for runway reconfiguration under discussion at SFO. NOAA Science Panel I was the result. Responding to a formal request by BCDC, joined by all of the other state and federal regulatory agencies with jurisdiction over any permits SFO would need to build the proposed project, NOAA formed the "San Francisco Airport Science Panel," now know popularly as "NOAA Science Panel I."

The first NOAA Panel's charge was to identify the key scientific questions the Airport should address in any environmental reviews conducted to support new runway construction. The Panel, comprised of independent scientists with expertise in hydrodynamics, sedimentation, water quality, contaminants, and biological resources met in October 1999 to identify these issues and to present them in a public meeting held on October 20th. NOAA Panel I made the following general recommendations:

- Research and assessments conducted for the environmental reviews should be peer reviewed and the data made available to the public.
- If the runways were to be built, a carefully crafted long-term monitoring program was essential to understand impacts.
- BCDC, in cooperation with many others, should facilitate the development of an integrated research program designed to respond to the requirements of decision-makers.
- As research is conducted, the "no action" alternative should be considered along with various project alternatives given that the Bay is a changing, evolving system.
- Any runway construction should be designed to incorporate "adaptive management" so that as information about the Bay and how it works is gained the project is changed appropriately.
- Scientists and engineers should search for innovative solutions that minimize impacts.

These are themes to which NOAA Panel II would return often. The Panel also offered very specific recommendations about what research questions should be addressed in hydrodynamics, sediment transport, contaminants, habitat loss, biology, and in other areas.

The full Panel I report may be found at
http://www.bcdc.ca.gov/ic/ic_sfo/noaa/noaapanel19991019.htm

Independent Scientific Peer Review Panel

In 2000, the Project Management Team formally began the environmental review process with URS as the lead consultant. Incorporating a recommendation from Panel I, URS appointed a peer review panel that included external consultants, some members of NOAA Panel I, and URS staff. Although a positive and important step, this review group did not constitute "independent" peer review because the Project Management Team itself sponsored it. At the same time, SFO and the FAA began to refine runway project alternatives, and to engage the new Multiagency Task Force in discussions about the project and the permitting process. The Multiagency Task Force included all of the regulatory agencies that would review permits for the runway project and served as the Project Team's "single point of contact" for the regulatory community.

In November 2000, the Bay Conservation and Development Commission initiated discussions with NOAA about establishing the independent peer review NOAA Panel I had recommended. When brought into the discussions, SFO and the city's Office of Environmental Review quickly affirmed the value of conducting the review outside of the Project Team and worked with NOAA and BCDC to outline a protocol for establishing NOAA Panel II. The document that describes the relationships among NOAA, the regulatory agencies, SFO and the rest of the Project Management Team, and the Office of Environmental Review may be found in Appendix II. In addition to providing policy support, the Airport agreed to fund a significant part of the Panel's operating expenses. NOAA and SFO signed a formal memorandum of understanding which described roles and responsibilities—including the Panel's independence—and provided for the transfer of funds in the spring of 2001. The agreement may also be found in Appendix II.

Drawing first on participants in NOAA Panel I, the Panel Chair, Dr. Jerry Schubel, and NOAA Panel staff began to select Panel members in consultation with the Multiagency Task Force. In addition to seeking appropriate expertise in physical processes, water quality and contaminants, wetlands and habitat, and biology, conflict of interest, and other important criteria were used to select Panel members. Scientists who were employed by regulatory agencies that would review permits were disqualified, as were scientists who had served as consultants to URS or SFO in the past. Because URS had compensated Panel I members a small amount for participating in the initial internal review, Panel II staff designed a compensation scheme to ensure all eligible Panel members received the same honoraria for participating (scientists employed by the federal government are not eligible to receive such honoraria). For their service over two years, each eligible Panelist received an honorarium of $4,500 and reimbursement for travel costs incurred.

The NOAA Role

NOAA is a diverse agency with many roles and responsibilities. The agency's management, regulatory, and permitting role in fisheries and habitat conservation is often most visible, but much of the agency focuses on providing data and information, decision support tools, and other services to promote sound decision-making in the coastal zone. In managing both Panel I and Panel II, NOAA served as a neutral "broker" with no position on the proposed runway project and no vested interest in the outcome of the public decision-making process. NOAA's Fisheries Service, which would have reviewed any Airport permits for endangered species and habitat conservation issues, was, along with all of the other members of the Multiagency Task Force, a beneficiary of the NOAA Panels' assessment and review process. Were the project to have gone forward, the NOAA Panel would have remained neutral and the NOAA Fisheries Service would have conducted permit reviews consistent with its statutory mandates and mission.

In addition to limited funding, NOAA provided the Panel staff, which included a staff director, an on-site representative, a contractor, and a graduate intern.

Peer Review

Independent peer review is a fundamental part of conducting science. It provides for an objective, disinterested evaluation of a project or study—an independent assessment of the scientific questions asked, the methods used to address the questions, and the conduct of the project or study—and for bringing to bear on the effort the appropriate expertise and knowledge. Peer review assures non-subject matter experts that the work done meets accepted scientific standards and that the conclusions drawn are supported by the data collected and the analysis performed. In short, independent peer review helps to assure that the scientific work performed is credible, reasonable, and reliable.

Although most consulting groups have internal review protocols, independent peer review for the science conducted for large projects in the coastal zone is unprecedented to our knowledge. Cost, schedule, and political constraints, and lack of a successful model have meant that independent peer review often is not a substantial part of developing the scientific and technical studies for environmental assessments of large projects. But the cost resulting from the failure to incorporate thorough peer review is high—the quality of the science itself becomes a contentious issue and the public debate focuses there, not on the merits of the project itself. Independent peer review helps to provide a common framework of scientific understanding to support regulatory review of large, complex projects, reduce disputes about the quality of the scientific work conducted, and helps place debates about these projects where it is most appropriate—in the public decision-making process.

Driving Questions

The Panel used a set of driving questions to frame its peer review:

- Did the Airport's consultants ask the right scientific questions about the proposed project's potential environmental impacts on San Francisco Bay? Were the scientific and technical studies to address these questions designed and conducted properly?
- Are the conclusions the consultants reached in these studies supported by the data collected, information generated, and analyses performed? In other words, are these conclusions scientifically defensible?
- What level of uncertainty is inherent in the projected environmental impacts of the proposed runway configurations given the scope of the task and the limitations of science?
- What additional studies, if any, are required to evaluate as completely as possible the environmental impacts of the proposed project—during and subsequent to construction—within the context of the scope of the technical studies?

These questions were the basis for the Panel's comments to the Project Team during the review process. Questions about whether the impacts the studies predicted were reasonable or acceptable, or whether the runway project should be built do not constitute "peer review" and were not addressed by the Panel or its members.

"Rules of Engagement"

The process of developing scientific and technical studies to support Environmental Impact Statement and Environmental Impact Review documents is substantially different from conducting research in a university or government laboratory. There are specific statutory requirements that must be met under the National Environmental Policy Act and state counterparts such as the California Environmental Quality Act—there are a limited set of questions that fall within the scope of these studies. Further, there are usually rigid schedules for completing the studies, and cost is always a limiting factor.

The Panelists, on the other hand, wanted some assurance that their recommendations and comments would be taken seriously and that their investment in time would be repaid by the Project Team making a concerted effort to incorporate the Panel's review comments into the study as it developed.

To address the possibility that the Panel might make recommendations the Project Team could not incorporate because doing so would be outside the scope of the studies, create unacceptable disruptions to the schedule, or impose unacceptable costs on one hand, and to ensure the Panel's comments would be addressed on the other, the Panel and the Project Team agreed to "rules of engagement:" the Panel would conduct its review as it would any peer review, but would limit its activities to the driving questions stated above. The Project Team would respond to each of the Panel's comments in one of three ways:

- Agree to and address the comment or recommendation
- Disagree with the comment or recommendation and state why
- Engage the Panel in a discussion about the issue to clarify it or to seek common ground

In all iterations of the various sections of the report, the Project Team responded to comments and suggestions with either an oral discussion or written responses, often followed by more discussion and clarification. The contractors occasionally engaged Science Panel members in discussions regarding options for data analyses or methods for displaying information. Where there was a clear difference of opinion between the contractors and the Science Panel members, the issue was noted as an area of uncertainty in the report. Often the areas of uncertainty were a result of the lack of general scientific understanding, not necessarily a function of the quality of the studies that were done for the project.

Panel Meetings

The Panel developed comments on each draft of the technical studies report it reviewed. The comments usually followed a meeting of the Panel. The Panel held most of its meetings at the Romberg-Tiburon Center of San Francisco State University in Tiburon, CA. Panel meetings required extensive interaction with the consultants and to a lesser extent, with the other members of the Project Team. The Project Team participated in all of the Panel meetings. Members of the Multi-Agency Task Force were also invited to join the meetings as observers. The Panel provided copies of its comments to the Project Team and to the Multi-Agency Task Force.

Because the Panel's meetings were open only to the Project Team and the Multi-Agency Task Force, Panel staff met periodically with the environmental community to apprise them of the status of the Panel's review and to provide other information about the process.

Consensus-Based Review

The Panel operated on the basis of consensus: during discussions, the Panel attempted to address all of the major concerns held by any Panelist and worked to achieve common ground where there were differences in opinion or perspective so that each member of the Panel could accept and support the Panel's comments and other formal statements. This document is a consensus report of NOAA Science Panel II.

III. A Short Description of the Proposed Project and the Technical Studies

Project Alternatives

The Federal Aviation Administration and San Francisco International Airport proposed new runways to:

- Reduce weather-related delays
- Accommodate projected increases in air traffic at SFO; and
- Accommodate proposed new Very Large Aircraft (VLA) on airport taxiways.

The project involved reconfiguring existing runways, taxiways, and support infrastructure and building new runways in San Francisco Bay. The Project Team proposed three different runway construction alternatives and designed the scientific and technical studies to address potential impacts from the construction and operation of these alternatives.

SFO was built in a configuration typical of airports of the 1940s or 1950's. Two sets of parallel runways intersect midfield; the parallel runways (1-19 Right and Left) and 10-28 (Right and Left) are 750 feet apart, centerline-to-centerline. SFO's ability to use the runways is limited by the fact that the runways intersect and because simultaneous approaches to the runways can be conducted only in weather that allows for visual approaches. FAA standards require that runways be separated by 4,300 feet for simultaneous instrument approaches in poor weather. The proposed project would have allowed for simultaneous approaches by separating parallel runways by the required 4,300 feet to increase traffic volume during bad weather and so reduce weather-related delays.

SFO had projected that the high demand for flights in and out of SFO of the late 1990s would continue to grow, necessitating new capacity for takeoffs and arrivals. By increasing the Airport's ability to handle traffic in both good and bad weather, the project would have accommodated projected increases.

Finally, the project would have accommodated Very Large Aircraft such as the Airbus 380, scheduled for delivery to airlines in 2006. These aircraft, designed to carry between 555 and 820 passengers, will have wingspans over 260', 50' greater than the largest passenger aircraft now in regular service, and will require greater separation of taxiways for wing-tip-to-wing-tip clearances.

Each alternative was developed under the assumption that one of several construction approaches might be used: construction on pilings, construction on both pilings and fill (referred to as "hybrid" construction), and construction on fill. Each construction option would have various amounts of dredging, fillings, and pile driving; all with varying environmental impacts. The FAA and SFO would have selected the construction approach later in the design and development process.

- <u>Alternative A-3</u> would have involved the construction of a new runway in the Bay 9,400 feet long, along with a parallel taxiway to service it. Other changes would be made to the existing Airport infrastructure to accommodate the new runway and new runway safety areas would be added to the ends of the existing runway 1-19 and 10-28 systems. Alternative A-3 would involve between 3 (hybrid) and 13 (platform) million cubic yards (mcy) of dredging and between 5 (hybrid) and 21.3 (platform) mcy of fill.
- <u>Alternative BX-6</u> would have involved the new runway as described for Alternative A3; in addition, the existing runway 1L/19R would be converted to a taxiway, the existing 1R/19L would be extended 3,600 feet to the north, and a new runway built to the east 9,600 feet long. Alter-

native BX-6 would have involved between 11.2 (hybrid) and 16.2 (platform) million cubic yards of dredging and 19.4 (hybrid) and 31.8 (platform) mcy of fill.

- Alternative BX-R called for a similar configuration as BX-6, except that the 1/19 system would have been relocated and the existing 1R/19L would have been extended 6,250 feet. This alternative would have involved between 16.4 (hybrid) and 22.9 (platform) million cubic yards of dredging and 30.6 (hybrid) and 45.1 (platform) mcy of fill.

Any of these alternatives and construction approaches would have involved construction between 2007 and 2013. Dredging operations, depending on the alternative and the construction option used, would have been on-going 24 hours a day, seven days a week during runway construction.

More detail on the runway alternatives and construction approaches can be found in Chapters Four and Eight of the technical report and on the SFO website at http://www.flysfo.com/about/runway/index.asp

Technical Report

To evaluate the potential environmental effects of these runway alternatives and construction approaches, the Project Team conducted a series of studies. As noted elsewhere in this report, the technical report the NOAA Panel reviewed was only a subset of the work that would have been done had the runway project gone forward. These studies focused on collecting baseline environmental data, and the development of impact methodologies that are being used to predict the possible changes in the physical environment based on each alternative. Areas of study included baseline assessments of:

- Affected Biological Communities, including reviews of habitat types and identification of plankton, plants, fish, shrimp, and crabs; birds, marine mammals; assessments bioaccumulation and food web toxicity; threatened or endangered species; and wetlands;

- Affected Hydrodynamics, Sediment, and Water Quality, including reviews of the physical oceanography of the Bay (tides, circulation, waves, freshwater flows, bathymetry, sea level rise, sediment transport and sedimentation); sediment quality; and water quality.

The Project Team then evaluated these baseline assessments against a no project alternative (that is, considered change in a dynamic system) and each of the four build alternatives.

These studies resulted in a technical report entitled *Predicted Changes to Hydrodynamic, Sediment Transport, Water Quality, and Aquatic Biotic Communities Associated with SFO Runway Reconfiguration Alternatives BX-6, A3, and BX-R*. The technical report identifies and evaluates the possible changes to San Francisco Bay's biological, chemical, and physical characteristics that could result due to reconfiguring SFO's runways. This report presents analyses of in-Bay changes the alternative designs could cause. It also considers the use of Bay sand to construct the platforms and the storage of fill sand in Rehandling Basins created for the project and evaluates changes that could occur if Bay sediments are dredged to create access channels for construction equipment.

Availability of Technical Report

The technical report is available for review in hard-copy at the Main-San Francisco Public Library, the Main-Oakland Public Library, Main-San Mateo Public Library, San Bruno Public Library, Belvedere-Tiburon Public Library, MTC-ABAG Library, and at the Foster City-City Hall. Copies of the report in CD format can be obtained by contacting Camille Garibaldi (camille.garibaldi@faa.gov) or Paul Maltzer (paul.maltzer@sfgov.org).

IV. The Driving and Defining Questions

When the Panel met for the first time in May 2001, Dr. Schubel defined the work of the Panel with a set of driving questions. These questions guided the Panel's work over the next two years as it first reviewed study methodologies and then drafts of the scientific and technical studies the consultants prepared. In its preparation for the Public Forum in June 2003, the Panel addressed each of these questions, as well as several others relevant to the process. Before the Public Forum, Dr. Schubel polled each Panelist for their reactions to the Project Team's work. This section documents the Panelists' responses to the scientific and technical studies in general. Not all Panelists commented on all questions.

A. Scientific Questions and Conduct of Investigations

Did the Airport's consultants ask the right scientific questions about the proposed project's potential environmental impacts on San Francisco Bay? Were the scientific and technical studies to address these questions designed and conducted properly?

It is the Panel's view that for the studies it reviewed, the consultants asked the right scientific questions about the proposed project's potential impacts on the Bay. It is important to note, however, that the studies the Panel reviewed were only a subset of the technical and scientific studies required to assess impacts completely or to develop an Environmental Impact Statement or Environmental Impact Review. The consultants conducted the scientific and technical studies correctly. As is inevitable in a study of this magnitude, Panel members and the consultants disagreed in some areas, but these disagreements do not undermine the overall quality of the studies. Some apparent omissions from the report were due to contractual arrangements and the fact that the SFO project has been terminated, not to poor science. These issues were to have been addressed in other studies, now canceled.

> State-of-the-art numerical models were used to evaluate hydrodynamics and sediment transport. Available San Francisco Bay data sets on hydrodynamics, suspended-sediment concentrations, and bathymetry were used to calibrate and test the numerical models. New data were collected to fill data gaps. David Schoellhamer (DS)

> The report that we have had the opportunity to review represents a significant scientific body of work and has made a contribution to our understanding of San Francisco Bay. Its components have addressed a number of important descriptive elements for the marine environment. Each of these individual components has been carried out with professionalism using strong technical components. Consequently they have added a number of views on various components of the marine environment. Jerry Galt (JAG)

> At the synthesis level the task becomes more difficult. Here the goal was to link components to provide an increasing level of inference on how the interdisciplinary components interact with each other; and how changes induced by the Airport construction might alter future conditions. Over the course of the project the researchers tied their results to a sequence of conceptual models that became more refined and provided progressively better insight into the Bay's environmental processes. In a number of cases sensitivity analyses were carried out to indicate where system variations descended into unresolvable noise. Overall this was an impressive effort. No catastrophic ecosystem perturbations due to runway construction were indicated by the analysis. (JAG)

> The basic approaches and scientific methods used in the report generally followed those that are accepted by the scientific community. URS performed literature searches, collected and analyzed new samples from the site, interpreted information from the literature and the new

analyses, and applied that information to models and forecasts of the effects of the runway reconfiguration. This basic approach is widely accepted and entirely consistent with most scientific methods. Where they had several options from which to choose, URS often selected a comprehensive (as opposed to incomplete) set of methods or protocols to follow to ensure that their conclusions were based upon sound science and a weight-of-evidence approach. Ed Long (EL)

URS put a great deal of work into trying to address areas of contamination and toxicology using state-of-the-art methodologies and the most recent data for San Francisco Bay. When there was insufficient site-specific information on toxicity in the Bay, appropriate extrapolations were made from the results of studies conducted elsewhere. To the extent possible, the extrapolations were made for similar species and similar estuarine resources. Russell Flegal (RF)

URS used the appropriate tools (models and analyses). The hydrodynamic and sediment transport modeling was particularly well done. I have not seen anyone else link several types of models together for their analyses. They did not interpret the benthic results as I may have, and in the case of the water quality, settled for less rigorous data than I would have preferred, but the tools used were appropriate. Bruce Thompson (BT)

URS used standard sampling and data analysis techniques to draw the reasonable conclusion that, other than the permanent loss of habitat and biota at the location of new runways, and the temporary disturbance of habitat and species populations during dredging operations, there are no clearly identifiable long-term impacts to the benthic community of South San Francisco Bay that could be distinguished from the normally large seasonal and interannual variability in species composition and abundance. Frederic Nichols (FN)

URS used standard avian field methods to evaluate bird populations utilizing the immediate vicinity and surrounding areas of the project. For the "far field" effects, they referenced appropriate sources to describe bird populations using the South Bay area. Janet Hanson (JH)

B. Conclusions Supported by the Analysis

Are the conclusions the consultants reached in these studies supported by the data collected, information generated, and analyses performed? In other words, are these conclusions scientifically defensible?

It is the Panel's consensus view that the data and analysis support the conclusions the consultants reached.

Hydrodynamic, sediment transport, and geomorphologic findings are supported by data and information in the report. The report also presents the assumptions made to develop the findings, as well as the limitations and uncertainty of these findings. (DS)

URS was careful to draw conclusions from the data and information that were compiled and interpreted, as opposed to relying upon their personal opinions and experience. The conclusions that were presented were based upon the data presented in the report. (EL)

It appears that the consultants' findings are consistent with the data and other information they are based on. In some cases they arrived at the same finding using two independent methods. They also compared their findings with those of others in the peer-reviewed scientific literature. (RF)

For water quality, there will always be doubt in my mind, because of their use of "non detect" data. For benthos, the basic community species and abundance data are there and were very well done. It will serve well for future comparisons. (BT)

The findings with respect to benthic community impacts are supported within the context of the background variability mentioned above. (FN)

The report presents adequate support for anticipating effects of Airport construction on fishes in the immediate vicinity of construction, but effects on fishes some distance away cannot be anticipated until effects of construction on the Bay's physical features (water quality, suspended sediments, current patterns, etc.) have been determined. Speculation concerning near field effects on the fishes is at this point unsupported. (I do not refer to Bay-wide effects here, but to the areas adjacent to and in the general area of the proposed project.) Ted Hobson (TH)

The conclusions made concerning the lack of effects on seal haul-out areas are stronger than warranted by the data and analysis and the spring 2000 aerial seal counts do not accurately describe seal haul-out use in the Bay. Diane Kopec (DK)

C. Uncertainty

What level of uncertainty is inherent in the projected environmental impacts of the proposed runway configurations given the scope of the task and the limitations of science?

It is the Panel's view that the URS scientists have produced a credible effort to reduce uncertainty in the physical modeling conducted as part of these studies and to understand and properly categorize the considerable uncertainty that remains given the state of the science. Those efforts, combined with other assessment approaches and comparisons of the effects of other large projects in the coastal zone will yield the most robust results. To the extent certain studies were not completed, however—such as a full assessment of the potential effects of the proposed project on the spring bloom—uncertainty remains that might be reduced through further study.

The degree of certainty achieved for hydrodynamic, sediment transport, and geomorphic processes is as high as it can be given the existing science and technology. The report reduces the level of uncertainty decision-makers face, but does not eliminate uncertainty. (DS)

It should be kept in mind that no single set of studies can possibly make up for years of episodic and piecemeal investigations. There are still numerous holes in the data that cannot be filled by even the most elaborate and careful analysis. This is particularly true of the complex trophic level dynamics that characterize the food web of biota in the Bay. Basic causative relationships are indicated in many studies, but reliable correlation statistics needed to make future predictions of mean conditions, or expected variations simply do not exist. (JAG)

All attempts to forecast the future are bound to include some degree of uncertainty. Descriptions of existing conditions are relatively simple as compared to predictions of the consequences of some future action(s). Descriptions of existing conditions can rely upon empirical observations, whereas predictions of future conditions must rely upon models, the relationships between independent and dependent variables, professional judgment, and past experience. In large part, URS selected widely accepted methods that had been previously published in the scientific literature to make these predictions. This does not mean that the projections of future conditions will not be erroneous. The data that are currently available or the relationships between variables that were previously published by others, or the basic models may be flawed in some way and, therefore, could lead to errors in conclusions. By using the basic approaches and methods that were previously accepted by scientific peer reviews, URS took an approach that would tend to minimize the uncertainty in the conclusions that were drawn. (EL)

Toxicological studies of risk assessment are, by definition, based on probabilities. These contain recognized uncertainties. These are evident in the URS report, which follows established protocols for such analyses. (RF)

The water quality models directly address concerns with accuracy and precision. Where possible, the URS tested their models by comparisons with independent reports by others, using different methodologies. These independent collaborations added creditability to the URS estimates of the uncertainty of their water quality models. (RF)

Given the extreme seasonal and interannual variability typically found in the benthic community of San Francisco Bay, the degree of certainty achieved in the conclusions of the study regarding potential impacts is consistent with what we know. (FN)

In my opinion, the level of certainty that can be derived from the current URS results, in combination with the results anticipated from the analysis reportedly underway for the EIS report, should provide decision-makers with reasonably adequate means to anticipate effects of runway construction on Bay fishes. (TH)

There is major uncertainty concerning the effect of fill and construction on migratory patterns of species of concern in the Bay. Construction noise and excessive turbidity could interrupt these migrations. John Stephens (JS)

The effects on bird and seal populations are predicated by changes in habitat, and to a lesser extent, increase in contaminant load and disturbances. Our understanding is that the hydrodynamic models cannot accurately predict the amount of habitat conversion that would occur to South Bay mud flats and other vital bird habitats. Therefore, the certainty we all want is not possible. (JH, Sarah Allen [SA])

The question of habitat conversion hinges on bathymetry. It would be useful to study other large fill projects in other parts of the world, or to study smaller fill projects here on the Bay and their long-term effects on neighboring mud flats and shorelines and incorporate these results into the analysis in the future. (JH)

D. Additional Studies

Given the large natural variability in the system, what kinds of studies (whether most appropriate for a project proponent like SFO or some other body) would it take to significantly reduce the level of uncertainty associated with their findings about the probable impacts of the various reconfiguration schemes?

What additional effort, if any, is required to evaluate as completely as possible the environmental impacts of the proposed project—-during and subsequent to construction—within the context of the scope of the technical studies?

It is the Panel's consensus view that the studies the Project Team conducted were comprehensive. The Bay system is complex, however, and there are areas—some of them outside of the scope of the environmental assessment for the Bay—where additional work should be done to reduce uncertainty or to enhance the studies completed.

The greatest uncertainty of the physical components in the report (hydrodynamics, sediment transport, geomorphology) is with the decadal predictions of geomorphic and habitat evolution in the Bay. Studies to improve simulation of geomorphic and habitat evolution in the Bay would also benefit tidal wetland restoration planning. (DS)

Perhaps the single biggest gap in the technical report is the lack of information gathered from scientific studies of other similar projects elsewhere in the world. The Science Panel urged the URS team on several occasions to pursue monitoring data from airport expansion projects in other bays and estuaries worldwide and apply that information to the predictions of the consequences of the SFO runway expansion. If such empirical information had been available for URS to review, it would have added a significant level of corroboration to the outcomes of the models that were used. However, the discovery by URS that such monitoring has not been done, even with construction projects of a large scale, suggests that the scientific community has little or no information on environmental impacts of large scale construction projects in estuaries. Studies of these kinds of impacts are needed. (EL)

Another important omission is a description of the operational effects of the reconfigured runways. Aircraft exhaust and other emissions from the operation of the runways were not addressed because the report was intended to focus only upon the construction-related effects of the reconfiguration. While this decision to disregard operational effects was consistent with the overall intent of the report, the potential environmental effects of the operations and the construction phases are irrevocably linked in numerous ways. For example, the report describes the capture and treatment of stormwater runoff from runways in swales to be constructed, but does not address the effects of aircraft emissions. Despite the rationale for addressing only the construction phase effects, the report, nevertheless, remains incomplete in this regard. (EL)

The entire South Bay area needs more targeted, intensive study. Special emphasis should be on the areas most likely to be most impacted by this and other large projects. (RF)

In my opinion, it is unrealistic to expect a sampling effort planned and executed during the preliminary stages of a project of this magnitude to produce the body of knowledge needed to properly assess its ultimate impact. Only a project manager lacking appreciation for the complexity of natural systems and the extent these systems change over time could expect to acquire the needed information this way. (TH)

That is why I have stressed the importance of searching the records of agencies and institutions engaged previously in Bay studies. Only by incorporating relevant information from a variety of sources is there any real hope of acquiring the temporal and spatial breadth of information required. (TH)

Referring to the BACI (Before-After-Control-Impact) model of impact assessment, it is very important to have good data on key processes and status prior to construction. And the data should span several years to get good estimates of spatial and temporal variability in those measures under pre-construction conditions. Then, similarly continue the measurements for several years after construction for the same reasons. Controls (or reference) conditions must be carefully selected. An independent entity (not SFO or FAA) should coordinate, plan, and review such a study plan. (BT)

Reducing the level of uncertainty in the predictability of other-than-local project impacts on the benthic community of South San Francisco Bay would require a spatially and temporarily intensive sampling program over periods of decades designed to distinguish quantitatively long-term trends from normal variability. Such a study would probably need to incorporate measures of animal tissue and sediment contaminant burdens and food web characteristics (e.g., changes in food resources), as well as species composition and abundance, in order to begin to tease apart potential causes of any long-term changes observed in the benthos. (FN)

History tells us that each of the many construction projects to be undertaken in the Bay during coming years will begin with its own investigation of environmental effects. And there will be little if any connection between these efforts, even though their effects on the environment are certain to be interrelated. There is a strong need for a coordinated research program for San Francisco Bay. While San Francisco Bay must be among the most intensely studied bodies of water on earth, research on the Bay by and large has not been coordinated. If it had been, it is probable that much of the knowledge needed to assess likely effects of runway construction could have been retrieved from an existing database created before there was even a recognized need for runway construction. (TH)

Clearly, there is great need of continuous monitoring of the Bay's biological and physical processes, such as the program of long-term assessments proposed by the Panel. It should be coordinated by an agency broadly connected with ongoing Bay research activities and interest groups, and include a concerted effort to incorporate historical information. It should avoid focusing on any specific project so that data and information gathered would have broad relevance for all projects that would disturb the Bay system. (TH)

In general, the fish element of the URS study began moving in the right direction very late in the process—at a time when it was too late to carry out the needed seasonal (or annual) components of such a study. I would like to see some elements of the multisampler program added to continued monitoring of the Bay or at least a single strong one-year baseline study with some of these techniques carried out to show the distribution of fishes—fishes that were likely under sampled by current interagency monitoring program techniques. When we first proposed a multisampling, the response we received was that these techniques worked well in southern California but were unnecessary on the central coast because of differences in the fish assemblage. Such does not appear to be the case. (JS)

To reduce the uncertainty associated with the potential effects on seal populations, the following studies are applicable: (1) enhance output of the circulation and sedimentation models to better assess whether existing seal haul out sites are vulnerable to changes in sea level, sedimentation, and erosion; (2) study habitat associations and foraging areas of seals in the Bay and determine if these areas change seasonally or annually. (Some studies are currently underway to identify these areas.); (3) determine if San Francisco Bay harbor seals have reduced immunity and productivity because of their current pollutant load; and (4) determine the direct and indirect effect of ambient and underwater sounds on marine mammals. This has the potential to be of interest because numerous piles will be placed in the area for several years. Indirect effects would include the effects on primary prey of pinnipeds such as Pacific herring. Direct effects could include changes in foraging areas due to various sound levels.

Spring Bloom

We know from long-term ecological investigations of South San Francisco Bay that phytoplankton primary production is the most important source of energy that fuels biological production in food webs supporting upper-trophic level consumers. These consumers include diving ducks, bottom-feeding fishes, such as halibut and sturgeon, and planktivorous fishes such as herring and anchovies. We know also that the rate of primary production is strongly light-limited, that the rate of primary production in San Francisco Bay is lower than in many other estuaries around the world, that much of the annual primary production occurs during the spring blooms, and that primary consumers (zooplankton and benthic invertebrates) are usually food-limited (i.e., do not grow at the optimal rate because the phytoplankton food resource usually is smaller than that supporting maximal growth rates). We also know that there are significant inter-annual variations in phytoplankton primary productivity and phytoplankton biomass and neither the causes nor the consequences of these fluctuations are fully understood.

The dredging and other construction activities the proposed project would require will suspend sediments and otherwise perturb the Bay system, at least in the near-field surrounding construction sites. A significant increase in suspended sediments generated by the project could affect light penetration on a large scale and thus primary productivity. There is a solid scientific rationale, therefore, for concern about the potential effects of runway projects on phytoplankton biomass and primary production and then propagation of those changes to the zooplankton and benthic invertebrates reliant on phytoplankton production as their source of nutrition. The question is one of scale—how large will the increases in suspended sediment be, and over what spatial and temporal scales?

Both growth rate and biomass influence system primary production, so a comprehensive assessment of project effects on system primary production should evaluate potential impacts on both biomass and growth rate (indexed as platinum-cobalt units, or PCU) in the assessments described here). The assessments here provide estimates of how different runway alternatives would change PCU, and they are based on contemporary conceptual models and the best available information about phytoplankton physiology in South San Francisco Bay.

However, the initial assessments URS conducted did not extend this analysis to process-based projections of how projects would influence system primary production because no assessments were made of potential impacts on phytoplankton biomass. Assessments of impact on primary production were based on altered PCU and a "typical" phytoplankton biomass, but this analysis presumed that the projects would have no effect on biomass. This presumption was not supported in the technical documents, and there was uncertainty about the extent to which projects would influence system-wide primary production in the traditional sense (i.e., the product of biomass times growth rate).

If the projects would have minimal impact on biomass, then the approach used here is reasonable. If the projects have a significant effect on biomass (and particularly during the spring bloom period when productivity is highest), then the initial assessment approach underestimated the potential effects of projects on primary production.

An additional source of uncertainty results from the potential effects of metal toxicity (of copper, for example) associated with dredging as an additional project-related impairment of primary production, because this effect was not included in the phytoplankton model.

A second limitation is the absence of projections describing how potential changes in system primary production would propagate to the next trophic level, and in particular to zooplankton and benthos. An important ecological conclusion from this assessment is that on an annual basis for the entire South San Francisco Bay, projects would lead to a reduction of primary production less than or equal to 2% of the existing condition. This conclusion should give rise to a series of questions about potential effects such as:

- Would this estimate change if it were based on a model that described biomass as a dynamic quantity that, itself, could be altered by construction disturbances and if other potential impairments of production such as copper toxicity within dredging plumes were included in the analysis?
- What is the ecosystem-level significance of a 2% decline in primary production, and particularly if this is sustained for nearly a decade of construction-related impacts?
- Is it possible that a decline of this (seemingly small) magnitude could have consequences for consumer biota (living marine resources harvested by people) if sustained over multiple years, and particularly because San Francisco Bay is a low-productivity ecosystem already?

In response to the Panel's request, URS used a simple, spreadsheet analysis approach to investigate the spring bloom. It represents an appropriate starting point and was endorsed by the Panel as a point of departure. Based on the simplicity of this approach, the indication of minimal impacts conveys a level of certainty that is greater than is warranted by the sophistication and resolving power of the analysis. It should be noted that there are more complex multivariate formulations that are used in modeling studies that are accepted as representing a richer and more insightful understanding of the processes controlling the onset, development, and decay of the spring bloom. It is possible that using these formulations, in conjunction with appropriate statistical geophysical forcing, could distinguish potential runway project impacts and provide a stronger answer to this obviously important question.

It is the strong recommendation of the Panel that given the importance of the spring bloom to the primary and secondary production of the Bay, that the recent advances in the understanding of the processes and phenomena that trigger and control the bloom be incorporated into a more sophisticated modeling approach. This recommendation is consistent with the advice given by the Panel over the past year and with the recommendation to use models that couple the physical and biological processes that goes back to the beginning of the Panel's interactions with URS.

We urge that the same degree of rigor and sophistication of modeling be applied to biological processes as has been applied to the physical processes. Biological processes and phenomena are more complex than the physical processes, in part because the physical processes confound them, and they are of greater interest to the public. The application of the most modern modeling techniques would give greater confidence in forecasted impacts of the proposed runway reconfigurations on ecologically important phenomena and on how any impacts might be manifested at higher trophic levels. We recognize that this is not a trivial undertaking, but believe the importance justifies it.

Members of the NOAA Science Panel have persisted in their interest in phytoplankton because of the critically important function provided by this community—food supply to benthic and pelagic food webs supporting diverse species such as sturgeon, flounder, juvenile Dungeness crabs, striped bass, cormorants, canvasback ducks, and harbor seals. Biological communities of South San Francisco Bay are dependent, either directly or indirectly, upon phytoplankton biomass as the primary source of calories and essential nutrients to maintain their growth, reproduction, and population maintenance.

South San Francisco Bay has been the focus of intense ecological investigation for over three decades, and from this investigation we have learned the following: (1) primary production by microscopic algae (phytoplankton and microalgae growing on mudflats) is the base of the food web; (2) the rate of primary production (the food supply function) is low in South San Francisco Bay compared to other estuaries; (3) low primary productivity is manifested as food limitation (suboptimal growth and reproduction) of benthic consumers (clams, amphipods, polychaete worms) and pelagic consumers (copepods); (4) food limitation disappears during blooms when phytoplankton biomass is high enough to sustain maximum rates of growth and reproduction of these consumers; and (5) the low productivity of South San Francisco Bay is a result of its inherently high turbidity, caused by high sediment concentrations that limit light penetration in water and the rate of system primary production. Therefore, a first order question is: "to what extent will increased turbidity (and other outcomes of project activities, such as mobilization of toxic contaminants from sediments) reduce primary production further?" Complete consideration of this question will include quantitative assessments of how the different project alternatives would impair phytoplankton growth rate, population dynamics (i.e., duration, spatial extent, magnitude of seasonal blooms), and system-level primary production. James Cloern (JCl)

Fishes

The initial URS sampling effort failed to provide information needed to evaluate effects of construction on fishes. More varied sampling devices and expanded temporal coverage were called for. In response to the Panel's repeated comments and at the request of the NOAA National Marine Fisheries Service (NMFS), the URS researchers were encouraged to do additional sampling in a variety of ways. The result was a reasonable representation of the fishes that occur in the proposed area of construction. (TH)

The samples taken, however, do not provide a basis for considering effects on fishes elsewhere in the Bay. The Panel emphasized the need to incorporate information available from Bay studies done by others elsewhere and/or at other times, as it was clear the URS fish group was unable to produce a satisfactory Bay-wide assessment. (In my opinion, it would be unrealistic to expect any research group to complete such an assessment, especially with the constraints under which the URS group operated.) The URS group responded by adding data from a long-term California Fish & Game (CAL F&G) survey, which could have provided valuable information. But although the Fish & Game survey was Bay-wide, the URS group drew data only from stations near the construction sites, which missed the point of the Panel's suggestion. (TH)

It is clear that URS recognizes the limitations of their results in regard to considering Bay-wide effects, as they now have a group analyzing existing published and unpublished reports by others in an effort to provide a Bay-wide perspective for the Environmental Impact Statement. (TH)

One limitation of the Panel process is that we were brought in after most of the studies had been designed and field research completed. I believe that they felt that the Interagency Ecological Program fish studies gave them all the information that they needed and their fieldwork essentially duplicated these techniques in the vicinity of the Airport. Our concern was that the limitation of these techniques which were designed to collect certain species, especially those of economic importance, was giving us a biased view of the Bay's fish assemblage and did not reflect the actual density and diversity of that assemblage in the Bay. We immediately called for a multisampler approach and were supported in this by fishery professionals from NMFS and CAL F&G. Unfortunately, the sampling was delayed until last summer. As a result, we have only one seasons' data that reflects the actual assemblage configuration. This is certainly better than nothing—but it is far from ideal. (JS)

Recent work by the contractor, along with members of the agencies, is beginning to develop species/habitat relationships, a tool that could allow analysis of habitat change due to water movement, fill, erosion, and sedimentation to give us information on loss of fishes. Again, it would have been better to pursue this line of effort earlier in the study. I am, however, unclear as to the changes in habitat that might be predicted by the various physical models. (JS)

We do have several estimates of areas to be filled under the different options and should be able to calculate fish exclusion loss from these sites. The contractors continue to be less than certain that loss of habitat will lead to a one-for-one loss of fish inhabitants. They may be right but need a model to describe their thoughts. (JS)

Cumulative Effects on Fish, Birds, and Mammals: Behavior and Habitat

Several very large construction and restoration projects are or will be occurring in San Francisco Bay over the next several years, which may contribute to large-scale impacts on the ecology or the biodiversity of the Bay. Examples of projects that could contribute to large-scale impacts in the Bay include the retrofits of the Richmond-San Rafael and Bay Bridges and the Port of Oakland dredging program. These projects will likely have effects on the presence and distribution of fish, birds, and harbor seals that forage, roost, or haul-out adjacent to these bridges and dredging and dredge spoil disposal sites. The temporary—or potentially permanent—displacement of seals from the haul-out sites at the bridges could affect the number and distribution of seals in the South Bay. Alternatively, the acquisition and restoration of the Cargill salt ponds may provide new haul-out and foraging habitat for seals and birds in the South Bay. Similarly, there are multiple activities in the Bay that are affecting fish habitat. If the SFO runway reconfiguration project would reduce or alter fish habitat, the cumulative effect of this alteration should be evaluated in the context of habitat loss throughout the Bay from all projects.

The potential effect of cumulative actions may have short- or long-term consequences for all biota in San Francisco Bay. The effects may be direct or indirect, and additive or synergistic. Direct effects of the project could include short-term disruption of normal activity for fish, birds, and marine mammals from increased noise or boat activity in the vicinity—the mitigation for these disruptions is relatively simple. (For example, the Richmond-San Rafael and Bay Bridge retrofit projects have addressed the potential negative effects of noise on seals and birds by altering the planned timing and location of their construction activities.) The cumulative, direct effects on fish, birds and seals of several projects under construction simultaneously in the Bay, however, could permanently alter the distribution of the animals. Harbor seals, for example, permanently abandoned a haul-out site at Strawberry Spit in the 1970s, in part because of a construction disturbance and likely shifted to a sub-optimal haul-out site in Sausalito.

More difficult to measure are indirect effects from redistribution of pollutants into the water column and through the food web. Again, there is ample literature indicating that harbor seals in San Francisco Bay are already burdened by a pollutant load that is potentially impairing their productivity. The use of models in assessing the addition of contaminants to the system does not account for the addition of contaminants from other concurrent projects. Indeed, the document lacks any references to the literature of results from studies of similar projects elsewhere that compare actual data on effects of dredging on biota. Nor does the document include information on the potential addition of pyrogenic and petrogenic PAHs from jet exhaust and the existence of these chemicals already in the biota.

Displacement or alteration of wildlife distributions could result in sub-optimal site usage within the Bay where animals may be exposed to other risk factors such as higher pollutant loads, or dispersal outside the Bay. For example, a change in aircraft flight paths could result in increased noise over resting or breeding areas, causing wildlife to alter use or abandon sites. There are a multitude of potential cumulative indirect effects of the project including habitat alteration due to erosion or loss of wetlands, which in turn could result in shifts in wildlife use. Increased sediment loads in the water column from several concurrent projects, for example, could reduce the ability of animals to detect prey due to turbidity or reduce prey availability. The report currently does not consider other ongoing projects in the Bay that could have an additive effect on turbidity, erosion, or sedimentation rates and consequent potential for habitat alteration. The report also does not consider the potential effect of global climate change on sea level rise and habitat alteration in the Bay. With sea level rise, foraging and haul-out site areas would change.

When evaluating the effects of the SFO Airport expansion, URS should consider in its analyses the potential effects of other large projects under construction in the Bay. URS should also consider the potential effects of projects planned for construction in the Bay over the next decades (e.g., additional channel deepening for the Port of Oakland). If possible, the effects should be analyzed quantitatively. (SA, JH, DK, RF)

The Need for Additional Studies Contingent on Selection of Particular Alternatives

As might be expected, there are broad sets of potential project activities for which potential impacts on San Francisco Bay systems must be assessed. Only a subset of the range of possible activities will be conducted if the proposed project is built because San Francisco International Airport and the FAA will select only one of the alternatives. A complete assessment of the proposed runways project cannot be produced until after pending decisions are made about specific alternatives, and after essential new information is collected following those decisions. For example, one construction alternative requires dredging at Hunter's Point. The sediments and their porewaters in this potentially highly contaminated area have not been sampled and contaminant concentrations have not been determined. Should a construction alternative be selected that involves dredging at this location, additional sampling and analysis must be conducted before it is possible to assess potential impacts. The Panel understands that such sampling and analysis would in all probability be required under the permit process.

E. Consultant's Responsiveness to NOAA Science Panel

To what extent was URS responsive to the comments of the Panel throughout the process?

During the peer review process, URS substantially changed its approach in some areas, conducted additional analyses, and rewrote or added major sections to the report in response to Panel comments. In general, URS was responsive to the Panel's concerns.

URS was very responsive to comments on hydrodynamics, sediment transport, and geomorphology. (DS)

Initial drafts of sections of the technical report on chemical toxicants and their biological effects included some errors and omissions, which when called to their attention were revised. The URS scientific team was in large part very responsive to suggestions and guidance from members of the Science Panel. For example, they followed a sediment quality classification scheme that was suggested. Some critical information necessary to make informed conclusions regarding the impacts of the runway reconfiguration was not available when initial drafts were prepared. New information in some cases was compiled by URS to fill these gaps. However, in other cases when gaps in the report were identified, URS either dismissed them as not important or as not within the scope of the report. As a consequence, the report remains incomplete on some technical issues such as human health effects, toxicological effects upon resident demersal fishes, and toxicological effects upon biota of sea surface microlayers. (EL)

URS was very responsive to any comments or suggestions I made throughout the entire review process. This included looking up references that were published well after the process had started, and in one case was still in press. (RF)

Overall, URS was very responsive, except with regards to one request for resampling trace organic contaminants to provide actual test results as opposed to "non detect" data. (BT)

URS has been responsive to our comments regarding impacts to the benthos. (FN)

Considering that URS is in business to make a profit, and responding to many Panel comments must have been expensive, I found them reasonably responsive to Panel comments. Some apparent failures to respond, I believe, may have resulted from misunderstanding what the Panel wanted. Whether this was due to an inability of URS researchers to comprehend or an inability of the Panel to communicate remains a question. Probably it's a little of both. (TH)

Under these limitations (cited above), the final report has done a reasonable job of presenting their analysis of the data and it is a far stronger report than it would have been without the Panel's prodding. (JS)

URS was very responsive to our suggestions. If clarification was needed, they called and we were able to discuss the options. (JH)

Given scheduling, financial, and logistical constraints, URS was reasonably responsive to questions and guidance provided. Financial constraints limited their ability to conduct additional studies that might have provided greater insights in the foraging areas and habitat associations of the seals. The final write-up was vastly improved from the earlier drafts. (SA)

F. The Contribution of the Studies to Knowledge about the Bay

How would you characterize the contribution made by the URS studies to our overall understanding of the Bay and our ability to evaluate perturbations caused by other proposed projects?

It is the Panel's consensus that the technical studies represent a significant contribution to our understanding of San Francisco Bay. How and how much the studies contributed depends on the programmatic area of study. In many areas, the URS modeling, data collection, or analysis makes an important contribution to the scientific understanding of the Bay. In others, the value is in the compilation and cataloguing of historical data, previous studies, and recent research. Taken together, the URS studies provide a major benefit to the Bay area community—never before has so much material about the Bay been brought together into one set of volumes. It is important that the FAA continue to make these studies available to the scientific community and to other interested parties.

The studies have provided improved numerical models of sediment transport and wind waves. The studies provide a better understanding of the uncertainties of evaluating how a proposed project may affect the Bay. (DS)

FAA, SFO, and the city of San Francisco have provided for a major scientific study of the Bay. It has contributed a significantly increased level in our understanding of the area. It did not highlight any massive ecological pitfalls predicted as the result of runway development. It does, however, not answer all possible questions that future area planners may have about how the region's marine environment will respond to new developments. This is particularly true of slight variations that might occur within the unresolvable noise levels of the present study. For this level of understanding the only thing that could enhance the decision-making capability of future planners will be a consistent and thoughtful monitoring program that San Francisco clearly deserves and for a magnificent estuary that will continue to be surrounded by a grateful community. (JAG)

For the areas that I focused on, the principal contribution of URS was to synthesize existing data and evaluate it in different ways and with different models. No new real information was generated in terms of the biogeochemical cycling of contaminants in the Bay, nor on the toxicity of those contaminants on Bay organisms. The models need to be validated with a sampling program. (RF)

In-depth understanding exists from the studies of USGS, IEP, SFEI, and other groups that have studied the Bay for a long time. URS contribution has been to take that body of knowledge and test it in an integrated and interdisciplinary manner focused on the SFO situation. In my opinion, it is the integration and testing that have been the most valuable contribution. Hopefully, it has set a high standard for evaluation of future projects in the region. (BT)

The URS studies have added considerably to our knowledge of the physical environment of South San Francisco Bay, have brought into one package a very useful synthesis of the major ecosystem characteristics of this region of the estuary, and have demonstrated the difficulty we face in detecting and evaluating the potential impacts of such a large project on habitats and species beyond the localized areas of construction disturbance. This will be an oft-referenced report. (FN)

The URS studies have made a major contribution to our overall understanding of the Bay as a natural system; in fact, to my knowledge it is the most comprehensive and informative effort to date. Its breadth provides relevance to concerns about effects of other projects, although this attribute is to some extent limited by its focus on runway construction. (TH)

They have created a unique and valuable source of physical processes, results, information summaries, and literature compilations, which clearly illustrates the complexity of the system. The conceptual model is especially useful and will probably find its first large use in the salt pond restoration process. (JH)

The URS study of marine mammals in this report was mostly composed of a literature search and one seasonal survey of harbor seals, so their contribution to the overall understanding of marine mammals in the Bay was not significant. Nevertheless, the contribution of overall understanding of the Bay as a natural system will provide a foundation for better understanding of marine mammal habitats within the Bay. (SA)

V. Summary Statements from the Public Forum By Study Area

The following material is taken from the transcript of the Public Forum held in San Francisco on June 25, 2003. It is provided here as the Panel's summary assessment of the work URS conducted in the different programmatic areas of study that comprise the final technical report.

Introduction

The role of science in public decision-making is to provide direction and guidance to the public, the regulators, and the elected and appointed officials who must decide. Our responsibility was to oversee the quality of the science performed by URS so that, as the public makes decisions about what it wants to do, the quality of the science would not be in question. This Panel urged URS throughout the process to look at as many lines of evidence as they could to reduce the level of uncertainty, and in our opinion they did a good job of examining historical data, information from other systems, and so on.

Does any uncertainty remain? Absolutely. Uncertainty is what drives science and though there is a quest to reduce it, it can never be eliminated. As new questions are answered, others emerge. Lynton Caldwell, in a review of Michael Zimmerman's excellent book, Science, Non-Science, and Nonsense, describes science as a process of "separating the demonstrably false from the probably true. It is a fundamental underpinning of science that only falsehoods, not truth, can be proven." And the late Richard Feynman, who received a Nobel Prize, said, "scientific knowledge is a body of statements of varying degrees of certainty, some most unsure, some nearly sure, none absolutely certain."

The final technical report was significantly enhanced over previous versions, both in terms of scientific veracity and its readability. Through the peer review process, we identified a number of areas for additional research, which are identified in this report. We believe this research should be carried out if the project moves forward in the future. The URS studies provide us with a set of modeling tools that will be useful in evaluating the hydrologic and sedimentalogical effects of other proposed perturbations to South San Francisco Bay. The hydrodynamic models were an appropriate choice. The existing sediment transport models were enhanced and the modeling of wind wave effects on sediment transport was a significant advancement. The integration of existing information and data with new data and information by URS constitutes an important contribution to our understanding of the properties and processes that characterize the Bay. It should not be surprising that there were no major new fundamental insights. This is a well-studied system and the properties and processes investigated by URS focuses on those that have received attention in the past using similar approaches.

The responsiveness of URS to our comments increased over time and with only a very few exceptions, they reached a level that provided members of the Panel with the level of scientific certainty they felt was sufficient for the assignment. Responsiveness could take several forms: they could agree with our suggestions and then go on and do the analysis recommended, or they could disagree and provide a rationale why they disagreed with us—both of those happened and there were only a few incidents where neither of these responses occurred.

This project was a major undertaking. There were dozens of scientists working on it over several years. Therefore, when it is described piece by piece, it sounds fragmentary. We should all be mindful, however, that the objective here was to take the various components of the studies and weave them together into a chain or sequence of inference that would allow decisions about environmental effects that might be caused by construction at the Airport.

The URS studies affirmed many things that we already believed. The modeling approaches were appropriate to the task, and if the spring bloom were to be investigated along the lines that we mentioned, it would require a different level of modeling. The one overriding recommendation that we have is that, if this process is to become a model for other peer review panels, the peer review panels should be involved from the very beginning, that is, during the planning phase before any field data are collected. The disconnect in time between Panel I and Panel II was unfortunate because several sampling programs had already been designed, and in some cases most or all of the samples had been taken before we started (although in some cases, it was possible for URS to go back and collect more samples).

We have completed our review. It is now up to the Bay area community to consider and apply the science as it makes its decisions.

Hydrodynamics and Physical Modeling

The first kind of question of interest in hydrodynamics and physical modeling is: "how does the water move around and what kind of stress can we expect on the bottom?" To assess this question, the consultants selected a well-known, well-recognized, extensively tested hydrodynamic model. This model does a number of things: it divides the Bay up into a lot of little boxes, and then it starts off with forcing in the Pacific Ocean. As the tides move up the California Coast, the water gets higher along the coast and, because of that, there is a slope of water through the Golden Gate Bridge, and there the water starts moving in correspondence to that pressure force. What happens then is it moves into the Bay, feeds itself around all the different little arms, gets down to the end of the Bay, eventually reflects off the sides, and sloshes back and forth somewhat like what you get in a bath tub if you wiggled around and watched the water. This model was particularly good at carrying out those kinds of physics.

One of the things that can be done is to start driving it with the tides offshore, going up and down, and then see how the water moves around inside the Bay and what it leads to. There are many, many places in the Bay where there are tidal data available—it is a wiggly line plot that you get on the fisherman's calendars. When this model compares against those kinds of data, it does very well. It moves the water around in the Bay, puts it in the right places so that when the water goes up, it goes up. For example, if it goes up two and a half feet, it goes up pretty much two and a half feet and therefore represents the tidal prism. This is the most obvious physical process that we look at. In moving that water around, you also get a good estimate of the currents. Picture dropping a chip of wood in the water, the way it would move is like the vector arrows moving around. Again, the model can be compared to a limited set of current measurements and it tends to do a good job in those stronger currents. In the channel there is a little weaker flow on the flats and so forth. Finally, the model can also predict how fast the water is moving over the bottom, and this is important because you are looking at stress, and how that stress will drag along the bottom and move the sediments around—this is an interdisciplinary program.

You can also put in a trench site and stir up some sediments and see where they go before they fall back down to the bottom. This kind of model is made up of small cells and it is closely configured to the geometry of the Bay, which is important to the tidal motion. Another implication of this is that it resolves the geometry quite well and you can actually change the geometry in a hypothetical way by pretending that you put in the runway, or the build-up configuration, or you have scooped out some of the borrow pit and so forth.

Since it does a good job on what you have already, it is highly likely that it is going to do a good job on the next phase, which is to modify the basin, as you would expect from the development that is proposed. Again, this kind of physical model is a good starting place in that it starts off with a strong geophysical forcing—the tides through the Golden Gate. It can then also add models that looked at the weight formation, for example, if the wind blows across the water, you are going to create waves, those waves cause some stirring and mixing, and that mixing then interacts with the sediment processes. Ultimately, the sediment processes interact with biological processes, and so it goes. This sets off a chain of inference, which the consultants used throughout the studies to help evaluate potential changes. In thinking about models, it is important to keep in mind that no model is any better than its underlying conceptualization—and there are some problems, processes, and phenomena that can only be investigated using models.

Sedimentation

Sediment transport is linked to other components of the study. Water motion moves sediment in the Bay. The Project Team developed and applied numerical models to simulate water motion, wind waves, and sediment transport in the Bay. Sediment transports absorbed contaminants, and therefore is part of the contaminant models used in this study. Sediment deposition and erosion changes habitats used by the biological communities in the Bay—another effect of sediment transport and geomorphology and an important reason to understand sedimentation.

Project components that affect sediment transport are the expanded runways, the borrow pits, the restored wetlands, and the dredging and handling of fill. At the request of the Panel, the Project Team has considered all of these components to different degrees. The sediment transport model simulates changes in suspended sediment concentration caused by tides and winds over periods of hours and weeks. The model was calibrated and validated using extensive suspended sediment concentration data collected by the U.S. Geological Survey. The spatial resolution of the model was 200 meters—in other words, the model cannot resolve changes in features smaller than 200 meters square. In order to simulate geomorphic and habitat change, the Project Team extrapolated or extended model results over decades. This extrapolation can substantially increase the uncertainty of the model results because, as is typical of models, small initial errors in the sediment transport model grow with time.

The Project Team reduced the uncertainty of the effect of project alternatives by taking the difference between the project and no project alternatives in the difference of those simulations so that the errors mostly cancel each other out. In order to evaluate and further reduce uncertainty, the Project Team at the request of the Panel hindcasted geomorphic change with the numerical model, evaluated the effect of existing runways and borrow pits on Bay geomorphology and habitats, and made some simple back-of-the-envelope calculations of sedimentation dynamics. Thus, methods other than numerical models were used to predict how the project would affect geomorphology and are described in detail in the report. In summary, appropriate numerical models, alternative analyses, and available data were used in a reasonable manner. Despite these efforts, science still cannot predict geomorphic and habitat evolution in estuaries with certainty and it is not realistic to expect a better prediction of geomorphic and habitat change with the existing science and technology.

Contaminants

Toxic chemicals enter the San Francisco Bay Estuary from numerous sources, resulting in concentrations in the water and sediments that can cause toxic effects in areas where the concentrations are sufficiently high. Generally these chemical concentrations are much higher around the perimeter of the Bay than down the axis of it or in the open waters of the middle of the Bay. It is important in any ecological risk assessment to address the issue of sediment contamination. URS recognized this issue early in the process and focused considerable attention on their sediment quality evaluation. Their characterization and classification of sediment quality at the site and on prospective dredge and fill materials followed, with a few notable exceptions, widely accepted and sufficient methods—methods that are commonly required of dredge materials in this country. Interpretations of data followed commonly accepted protocols that have been published previously in scientific journals and government manuals. They estimated the future concentrations of potentially toxic chemicals in the water and sediments that would be expected as a result of the construction. They also predicted the concentrations of suspended particulate matter that would be expected using their models. The possible adverse biological effects of these future conditions were estimated by comparing outcomes of the model runs with water quality standards, the sediment quality guidelines that are available, and effects levels published in the scientific literature. All of these are commonly used methods. The list of chemicals for which the analyses were conducted reflected analyses that are commonly used in monitoring programs nationwide.

Using acceptable methods, toxicity tests were conducted on sediment samples to determine if they were toxic or not. Estimates of ecotoxicological risk to fish, birds, and mammals generally were prepared with the analyses of data from a large body of scientific literature, an approach that is commonly followed in these kinds of studies. They were careful and consistently drew conclusions from the data and other information compiled for the report, and avoided interjecting their personal opinions. They also compared their results to those previously published in the literature. However, the responsiveness to comments and suggestions from the Panel was inconsistent. In some cases they responded satisfactorily to suggestions, while in other cases they considered and dismissed them with some other rationale. For example, they adopted a sediment classification approach that was suggested, but did not do specific additional sampling and analyses we requested to reduce uncertainty in some areas. Overall, however, the quality of the report improved as a result of the peer review process.

Generally, URS developed multiple lines of evidence to reduce uncertainty in their estimates of risk. These involved examination of monitoring data that were available, as well as data from their own samples they had collected. However, there were several sources of uncertainty that remained. For example, the report did not include aircraft emissions or construction-related emissions, such as dust, as a source term to the Bay. And they did not include estimates of human health risks attributable to consumption of contaminated fish. It is important to understand that these topics are outside the scope of this particular report. Had the project gone forward, work on these reports would have continued. Also, risks of possible effects to resident bottom dwelling fish were not included, whereas such effects have been reported for local fish in the Bay by other investigators. As to the chemical analytic detection limits and methods for PCB analyses, the data for sediments were sufficient to estimate risks of acute toxicity to invertebrates, but not for estimates of risk to wildlife.

It is important to point out that predicting future sediment and water quality and ecotoxicological conditions is extraordinarily difficult. Our opinion is that the URS studies represent our current understanding of the Bay and therefore is an important contribution. However, it is unfortunate that the studies did not address the ecotoxicological effects of air emissions added to Bay waters on aquatic resources.

Ecotoxicology

San Francisco Bay is arguably the most extensively studied estuary in the world, certainly in terms of the sources, sinks, and cycling of contaminants within the system. The URS group took full advantage of that relative wealth of data and information to incorporate into their study. This enabled URS to incorporate high quality data in their models to estimate the ranges of both the levels of contamination in Bay waters and sediments, and the extent of that contamination under different scenarios. The model of estimates have limitations, as previously pointed out in the discussions on the limitations to the physical and geological models that increase with complexity, and especially with respect to biological models and assessments. The maps they produced to illustrate the current and potential distributions of contaminants in San Francisco Bay waters and sediments indicate an accuracy that is too great. There simply are not enough data either for water quality or sediment quality to provide the level of resolution that their maps infer. As the URS study and our concurrent reviews of the study continued, we added new requests for the URS group to put their models in perspective by comparing the projected results of their data with the data generated by others using different methodologies, both in San Francisco Bay and elsewhere.

With regard to the modeling of the chemical contaminants in the water and the sediments, URS complied with all of the requests all of the time. More important, in making the comparisons, they found in some cases their results were remarkably similar to those that others obtained using different methodologies. These independent corroborations provide additional confidence in the applicability of the URS models of projected distributions of contaminants in San Francisco Bay waters and sediments. In summary, we commend the URS group for their responsiveness to our requests to use the best scientific data in their water quality models, and put the results of those models in perspective by comparing them to the results obtained by other investigators using different methodologies that have been published or are in preparation for publication. This protocol is the accepted methodology for advancing scientific knowledge.

Wetlands

The loss of the majority of wetland acreage around San Francisco Bay is of critical importance because wetlands are habitats for birds and mammals and endangered species. In light of this fact, there is substantial interest in trying to evaluate the impacts of large-scale projects, like the proposed runway expansion, on wetlands and other intertidal habitats around the Bay. As part of the overall Environmental Impact/Environmental Review process, URS was to develop a separate and more detailed analysis of wetland issues related to this project. That effort was canceled when it became apparent that the runway project would not go forward. In evaluating the direct impacts on wetlands (i.e., filling or dredging at the Airport location), the analysis is generally straightforward. The direct impacts are primarily on subtidal habitats, not intertidal mudflats and wetlands. The direct impacts on salt marshes involve just a few acres out of the 1,000 to 2,000 acres of total direct impacts.

The bigger unknown, compared with the direct impacts, is in evaluating the indirect and long-term impacts on wetlands and intertidal mudflats, i.e., what may happen to those wetlands that are outside of the Airport zone because of subtle, long-term changes in circulation and sedimentation. This concern for indirect impacts on wetlands is important because intertidal wetlands exist in a small range of elevations and are dynamic, and because factors like sea-level rise or changes in sedimentation rate can have significant effects on their long-term stability.

In evaluating the indirect impacts, URS used state-of-the-art hydrodynamic and sediment modeling, as well as the best available data. However, even with these approaches, there are large uncertainties in predicting indirect impacts resulting from shifts in wetland habitats. The challenge is in linking the physical models to sediment transport models to predicted biological changes. Each time we put different models or model components together, we increase the complexity and uncertainty of our predictions. The two biggest concerns in terms of the uncertainty of the model for predicting changes in wetland habitat are the scale of the model and the focus of the model. In terms of scale, the models are effective at predicting large-scale changes in elevations (on the order of a meter or more) and the resulting shifts in subtidal habitats. But intertidal wetlands are sensitive to much smaller changes in elevation—a change of 10 centimeters or more of change could lead to vegetation shifts or conversion from a vegetated wetland to a mudflat. Because the scale of the model output is much greater than the scale of sensitivity for habitat shifts, the model is not very useful in predicting these small-scale elevation changes that can result in habitat conversions. Furthermore, the models intentionally exclude intertidal wetlands and vegetated wetlands in simulating hydrology and sediment transport. As a result, the predictions of shifts in wetlands are based on changes in adjacent mudflats. These two issues of scale and focus remain as substantial challenges in predicting potential shifts in habitat distributions.

These challenges are a result of lack of data as well as the lack of tools. URS did use the best available tools, but the challenge of predicting geomorphic change remains a substantial one. Early in the review process, we recommended that URS add some additional analyses to support their predictions of long-term sedimentation changes, and they were responsive in doing that. For the most part, URS was responsive in addressing our concerns about the specifics of the model and other approaches, but the issues of scale and focus remained a problem and would require substantial additional work. In order to reduce that uncertainty, we need much better data on shallow water sediment dynamics and long-term sedimentation processes, as well as a better understanding in linking the relationships between suspended sediment concentrations and accretion rates on mudflats and wetlands. In summary, we think the model and the other analyses have gone a long way in addressing some of the shifts in the deeper water and subtidal habitats, but there still remains great uncertainty in addressing changes in intertidal wetlands and mudflats.

Primary Productivity and the Spring Bloom

This is the area where there was the greatest disagreement among Panelists, yet we still have consensus. The spring bloom is an important characteristic phenomenon of San Francisco Bay. It is important not only to the primary productivity, but also to the secondary productivity. At our request, URS conducted a simple kind of "spreadsheet analysis" of how runway construction might affect turbidity and, as a result, primary productivity during the spring bloom. Unfortunately, this approach did not eliminate all of the Panel's concerns. It did not provide a sufficiently high degree of certainty in terms of the forecasted effects on this important phenomenon. Given the importance of the spring bloom to primary and secondary productivity of the Bay, in fact to the entire food web, the Panel recommends that a more sophisticated modeling effort be undertaken, and that it include more complex, multi-variant formulations that are accepted as representing a richer, more insightful understanding of the processes controlling the onset, the development, and the decay of the spring bloom. It is possible—and we would underscore the word "possible"—that in using these formulations in conjunction with appropriate statistical geophysical forcing, one could distinguish among potential runway project impacts and provide a stronger answer to this important question. We recognize that this is not a trivial undertaking, but believe the importance of the phenomenon justifies further investigation.

Benthos

Benthos is the community of invertebrates—clams, worms, and crustaceans—that live on or in the bottom sediments in the Bay. These animals represent a very important food source for bottom feeding fish and diving ducks, and thus they are very important components of the Bay's food web. These species, in that they live in or on the sediments, also provide a vector for contaminants that are in the sediments because they feed in the sediments, as well as a vector for moving contaminants from sediments to fish and wildlife species that feed on them. They are a critical part of this system and a critical part of the well being of the Bay. The stated goal of the URS study of the benthos was to characterize the composition, distribution, and abundance of the community of bottom-living invertebrates in the South Bay that would potentially be disturbed or eliminated during the construction of the runways. The presumed effects of the runway project fall into two categories: construction effects and operational effects.

The construction effects were those associated with habitat disturbance, essentially with dredging or disposing of dredged material, or filling; recolonization after the cessation of any disturbance, and the potential in that re-colonization for exploitation by opportunistic exotic species. Once the new runways are built, one of the operational effects would be the loss of the soft sediment habitat under the new runways. Another would be increases in hard substrate associated with construction that would replace a soft mud environment. The result is a change in habitat for many organisms that will establish themselves, including many exotic species. URS consultants designed a one-time survey of the benthos in all of the regions that would be subject to dredging and dredged material disposal, borrow sites, rehandling sites, disposal sites, and construction sites. The data from the samples were analyzed with standard statistical techniques to distinguish the relationship between the species found at each location sampled and the characteristics of the environment there such as water depth, sediment type, and salinity.

To expand the geographic coverage and to verify the appropriateness of their identification of the different species assembled, URS consultants reviewed data from other studies. The results of these studies showed, like all previous studies of the benthos of South Bay, that while in general the species found were representative of the broader South Bay, there was considerable variability in the species composition from place to place within the Bay, and there were indeed several different discrete assemblages that appeared to be associated with either specific water depths or sediment types, or a combination of those. Also, none of the invertebrate species found at the sample sites was unique, and many of the species were found to be exotic species. At our encouragement, the study was expanded to include consideration of temporal variability in the benthos. In other words, "how much does the community at any site change from month to month and year to year?" It is in that context one has to look at impacts of any particular disturbance. This was possible through the examination of other available data sets where repeated sampling of individual sites over several years has been carried out. The analysis of the repeat sampling data confirmed what has been shown in many previous studies—that there is very considerable variation in the composition of the benthic community over all time scales examined. The combination of the spatial and temporal variability of the South Bay provides the context within which any specific human impact must be evaluated.

The URS consultants concluded after their studies that, while there would obviously be loss of habitat at the site of the runways and there would be changes in the adjacent habitat hard structures, and changes in the sediment regime around any new runways, there would probably be no measurable longer-term impacts in the broader South Bay community that could be distinguished against the background of the very large spatial and temporal variability that we mentioned in species composition. And this variation has many causes, both natural and human induced, including the constant arrival of new exotic species. The conclusion was that there were no measurable longer-term impacts away from the site of the runway that could be distinguished from this normal variability. In the context of the variability of the community of animals and the typically observed rapid recolonization of bottom sediments by these species that inhabit South Bay following disturbance —this recolonization is usually within months—the study's finding of no obvious long-term effects away from the runways themselves is reasonable.

Fishes

Fishes in the Bay ecosystem represent a complex of species well adapted to variable environments. Virtually all occur widely in other California habitats, and inhabit the Bay because they can tolerate the great variability there in such characteristic habitat features there as salinity, temperature, turbidity and flow. The projected runway construction, however, will introduce additional features that are outside their evolutionary experience, including increased noise and concentrations of certain chemicals. The

URS researchers were contracted to predict how the fishes would respond to being exposed to the combined effects of these variables.

The Panel was convened only after URS had designed and completed their field studies, which proved unfortunate because shortcomings were immediately apparent. The major problem was lack of diversity in sampling methods. URS limited it's sampling gear to otter trawls and beach seines for fishes, and plankton samplers for fish eggs and larvae. They based their sampling methods on those used by California Fish & Game in the Interagency Ecological Program, which had sampled fishes throughout the Bay for over 20 years. But while it is appropriate, if not mandatory, to limit the variety of sampling methods used in a program of such magnitude, the Panel concluded that needs of the runway project demanded that URS produce a more intensive and diverse set of collections.

It was strongly recommended that URS undertake additional fish samples that provided better data on diversity and abundance over both space and time. Additional sampling devices were suggested along with a schedule that incorporated seasonal effects. Despite initial reluctance to expand their sampling effort, URS finally complied, and the result was a significant increase in available knowledge of fish communities in the Bay as well as data that are capable of supporting ecological analyses.

The Panel recognized that no single study could produce the depth and breadth of data needed to support the analyses needed, and suggested that URS undertake an extensive search for relevant data collected by others elsewhere. San Francisco Bay is one of the most studied bodies of water on earth, and there has been virtually no effort to bring all existing data together, at least regarding fishes. URS incorporated data from a number such studies in their final report, which added significantly to their findings. The result is the most comprehensive site-specific account of Bay fishes ever completed.

It is generally accepted that fishes and other inhabitants of the construction site—those in the "footprint" of the runways—are certain to be eliminated. The concern is with organisms outside the footprint. It is possible to predict construction effects in areas immediately adjacent to the construction, as this is where the URS efforts were located, but what about effects elsewhere? The extent of effects throughout the Bay remains an unresolved area of concern. URS was in the process of addressing this concern with development of a Habitat Association Index that would enable Bay-wide predictions, but this effort was terminated when the entire Project was canceled.

All in all, the URS team did a good job with their analysis. Their study and their conclusions are reasonable and well supported by their data.

Birds

San Francisco Bay is a major stopover point for migratory birds on the Pacific flyway. It is vital to the survival of many species of water birds. For example, it is a site of hemispheric importance for the flyway shore birds of which 70% of that population is found in the South Bay. When this Panel was convened, URS was already well underway with avian surveys and literature searches. Our goal was to ensure that the research included all the major groups of birds likely to be affected by the proposed runway expansion; for example, shore birds and waterfowl, and also that the research included special species, particularly those already listed as threatened or endangered. URS used standard field methods to evaluate bird populations in the immediate area of the Airport. These protocols utilized different methods of detection and take into account many variables such as seasonality, tide cycles, time of day, and local movements. URS also sought out existing data sets on status and distribution, as well as other factors identified in the conceptual model, such as contaminants and fish eating birds. URS followed our recommendations for further fieldwork and data collection, particularly concerning California least terns.

All this work was necessary in order to construct a before and after picture of potential effects caused by the expansion project. The primary effects on birds in the immediate area of the project are those of displacement and probable mortality due to habitat loss and conversion. Predicting effects on the South Bay's bird populations hinges on predicting changes in South Bay habitats that would result from the project's six years of construction and long-term operation. Our understanding is that the modeling efforts predicted no significant changes in the South Bay's open water habitat, and that the models used, while the best available, are not sensitive enough to predict changes in its intertidal habitats such as the mudflats that provide important foraging for migrating and wintering shore birds. Models lose resolution as they move from the physical to the chemical, and finally to biological properties, as the complexity of the ecosystem grows.

It is also not possible at this time for the models to accurately predict the cumulative effects on birds of contaminants released into the water column by the dredging needed for construction or of noise and/or disturbance created by construction and operation. It is important to recognize the difference between a finding of "no effect" versus one of "no conclusion." The latter is true for the Project's cumulative impacts on the South Bay's bird populations, despite the best efforts of this Panel and URS thus far. This report pulls together all of our current knowledge of the Bay's ecosystem and the tools available today for evaluating its conditions, including the conceptual model, which will be valuable to everyone interested in the Bay's ecosystem and eventual restoration. This report also exposes the gaps in our data and understanding of this complex system, and how changes in its physical properties affect the birds dependent upon it.

Marine Mammals

While several species of marine mammals occur in San Francisco Bay, harbor seals are of primary interest as they are the apex predator and the only resident marine mammal found in the Bay. Harbor seals feed on Bay fish and invertebrates. Throughout the year, seals use isolated shoreline habitats called haul-out sites that are critical to the seals' health and reproduction. Seals habitually haul-out at particular locations around the Bay, year after year. The two potential areas of impact to harbor seals are changes in foraging and haul-out habitat, and changes in the accumulation of toxic contaminants. In general, there was a good discussion of potential changes to seal habitat with the following exceptions: the sensitivity of the sedimentation transport and hydrology models is not at the scale necessary to accurately predict if there will be changes at specific haul-out sites or foraging areas.

The models are designed to address deeper-water habitats and not intertidal mudflats and adjacent marsh habitats. The spatial scale is too broad to predict the potential changes in bathymetry around specific haul-out sites. There is limited knowledge of the linkages between the distribution and abundance of prey fish and seal foraging activity, and this limitation greatly increases the uncertainty of predicted changes in seal food availability and exposure to toxic contaminants associated with the proposed construction. Based on our recommendations, spring aerial harbor seal surveys were added to provide current information on seal numbers and reproduction in the Bay at the three active haul-out sites closest to the Airport. Several years of data will be required to determine the status and trends of seal numbers at these sites. Several supplementary studies that were scheduled for inclusion in the EIS are needed to fully assess project effects on seal habitat. These studies, which are not currently available, include the effects of noise on haul-out activity and prey availability, and the cumulative effects that other large-scale construction projects could have on the regional seal population in the Bay.

The technical report provides a good background description on contaminant levels in San Francisco Bay harbor seals and includes a discussion of the additive effects of selected contaminants, including

PCBs, PAHs, DDTs, and mercury. Existing levels of toxic contaminants in Bay harbor seals are comparable to levels associated with health effects in studies with captive harbor seals. The report focused on harbor seals as one of two species used to predict broadscale health effects on the ecosystem resulting from potential changes in contaminant levels associated with the Airport project. URS should be commended for including actual toxicity data from harbor seals, providing a sensitive indicator of potential health effects. Bioaccumulation simulation models were the sole method used to assess wildlife health risks from current and predicted levels of PCBs, mercury, and PAHs in the Bay. At our request, URS planned to verify the results of their contaminant bioaccumulation models with hindcast simulations, using existing contaminant levels in Bay harbor seals. If that analysis is completed, the results will reduce the uncertainty of the model predictions. This technical report was vastly improved during the review process. The Panel's ongoing input in the early drafts of the report stimulated additional field studies, literature reviews, and data analysis, most notably the discussion on additive effects of contaminants.

VI. Monitoring Needs

While recognizing the importance of the monitoring programs that exist for the Bay (such as the Regional Monitoring Program and the Interagency Ecological Program for the Sacramento-San Joaquin Estuary), the Panel continues to stress to the Bay community that our ability to predict potential environmental impacts of large projects in the Bay, such as construction of runways at SFO, will be limited until there is a sustained long-term monitoring program that could detect the effects of such projects on the Bay ecosystem from the large natural variability in the system. The first NOAA Panel recognized this as a crucial need, and NOAA Panel II has gone on record to agree even though sustained monitoring was not among topics covered by the scientific and technical documents it had been called on to review. Here we restate comments made by Panel I and add specific recommendations for monitoring programs that would substantially improve understanding the Bay. [1]

Using Long-term Monitoring to Validate Assessments

The assessments of project impacts described in this document cannot be viewed as highly accurate depictions of how any project alternative will change San Francisco Bay, because of limitations inherent in any effort to model and predict impacts on a complex, constantly varying system. Instead, these assessments are best viewed as a set of hypotheses about how the physical, chemical, and biological Bay system might respond to the placement of new runways and the construction activities to build those runways. In our judgment, the approach URS has taken is valid and reasonable in assessing the projected impacts in light of the state of the science and the tools available.

Our level of confidence in the projected impacts is greatest with the physical changes and associated alterations in patterns of sediment transport and accumulation except over decadal time scales where changes in sea level and freshwater inflow could overwhelm any changes caused by the Airport. Our confidence decreases with forecasts of changes that result from the coupling of physical, geological, chemical, and biological processes and how those are transmitted up the food chain. These reservations are not unique to San Francisco Bay; they would apply to other coastal ecosystems that have inherently complex, non-linear, and poorly understood interactions of these processes.

For any project of the magnitude of the proposed SFO runway reconfiguration project, there are uncertainties inherent in the studies and the findings that follow. No matter how technically sound and rigorous the assessments of effects of large-scale disturbances, there frequently will be surprises—unanticipated responses within the complex interacting physical-geological-chemical-biological systems.

[1] See http://www.sfei.org/rmp/presentations/2003meeting/Schubel.ppt for additional information.

As a result, a complete assessment of the suite of responses to the construction and emplacement of new SFO runways requires new monitoring programs designed specifically to document and measure changes in the Bay system associated with the runway project. This new monitoring should be coupled to a new program of research geared to fill critical gaps of knowledge that limit our capability to forecast ecosystem responses to perturbations such as the proposed runways and the construction activities associated with them.

Nevertheless, had a long-term research and monitoring program been in place before URS undertook its studies, our collective understanding of the Bay and our ability to forecast potential impacts would be far greater. We reiterate our united conviction that the ultimate assessment of project impacts will only come from a measurement program in San Francisco Bay designed to test the individual hypotheses developed by URS and their associates. We encourage the permitting and regulatory agencies and interested stakeholder groups to use these hypothesized responses as a framework for designing and motivation for launching a monitoring program now, before we lose the opportunity to measure pre-project conditions. This construction and Bay-fill project is of such magnitude that it warrants a dedicated program of study and surveillance to document changes in the physical-geological-geochemical-biological system of San Francisco Bay and to verify that project impacts will be consistent with those described in this report.

Specific Elements of an Integrated Bay-wide Monitoring Program

The Panelists identified a series of parameters and processes that should be monitored as part of an integrated Bay-wide program:

- Nutrient analyses throughout the Bay
- Phytoplankton abundance and community structure
- Zooplankton monitoring in the South Bay (to parallel the North Bay and Delta efforts)
- Primary production, oxygen consumption, system metabolism, sulfate reduction, and other measures of ecosystem processes
- Patterns of distribution and species composition of benthic invertebrates
- Patterns of distribution and species composition of fishes
- Quantitative surveys of resident and migratory bird abundance and distribution
- Quantitative surveys of marine mammals with special emphasis on harbor seals, including abundance, distribution, haul-out sites, and marine foraging sites
- Microbiological community populations and functions in the water column and in sediments
- Infaunal benthos, chemical concentrations, and toxicity in surficial sediments
- Zooplankton population, toxicity, and chemical concentrations in the sea surface microlayer
- Persistent toxicants and histopathological disorders in demersal fishes
- Contaminant levels in birds and marine mammals, particularly PCBs, PAHs, DDTs, and mercury
- Assessments of reproductive success for water birds in the South Bay

- Water, salinity, sediment, and chlorophyll fluxes at sub-basin boundaries
- Water quality in tidal creeks and sloughs
- Water quality in the southern reach of San Francisco Bay
- Water and sediment inputs from Bay tributaries
- Shoreline changes
- Sediment bed dynamics: bed condition and mixing, response to storms and floods
- Decadal bathymetric surveys of the Bay
- Effects of wetlands restoration on Bay systems
- Wetland condition, elevations, vegetation coverages, and distributions

Characteristics of an Integrated Monitoring Program

Simply monitoring for particular elements, however, is not enough. A monitoring program must be designed carefully to yield data and information of value to scientists, decision-makers, and the public. An integrated monitoring program is designed to:

- Test hypotheses or answer specific questions
- Provide a statistically valid and spatially comprehensive sampling strategy that allows scientists and managers alike to track quantitative changes in the estuary over the long term
- Build at least in part on the foundation of existing longer-term data collection programs such as the Regional Monitoring Program, the Interagency Ecological Program, and the work USGS has conducted over the years
- Include a suite of meaningful indicators or "performance measures" that can be used to demonstrate the effects of specific human interventions (stressors as well as restoration/recovery activities on Bay systems, flora, and fauna). It is important that the public understand these indicators
- Include indicators of important physical characteristics such as sediment inputs and changes in the Bay margins (i.e., erosion and accretion trends) at a scale appropriate to predict changes in critical shoreline habitat in each region of the Bay-Delta system
- Track changes over time in acres of specific habitat types in each region of the estuary
- Measure critical contaminants (selenium, mercury, PCBs, PAHs, pesticides, etc.) in suspended and bottom sediments and in species of concern such as fish, ducks, and marine mammals
- Include a data management system that assures data quality, provides for long-term data storage, and allows for ready retrieval by interested parties
- Include provisions for the timely translation of data into information designed to meet the needs of different stakeholder groups
- Include an outreach and education component that focuses on engaging the public in the program's activities

- Include regular reporting of finding and trends to resource managers and the public.

For more information on integrated monitoring programs, readers are referred to "Managing Troubled Waters," a report of the National Research Council available in "Openbook" form at http://www.nap.edu/books/0309041945/html/.

Appendix I

Commentary on Key Report Topics

The SFO Runway Configuration Project contemplates a disturbance to San Francisco Bay of a magnitude unmatched in recent decades. Construction activities would continue 24 hours a day, seven days a week for nearly eight years to build two runway structures, each comparable in size to the Golden Gate Bridge. The project would create borrow pits up to 750 acres in size and a rehandling basin that could cover 60 acres. It is reasonable to assume that these construction activities and permanent emplacement of new runways of this dimension would cause irrevocable changes in the physical, geomorphic, and chemical character of South San Francisco Bay and its biological communities.

The question at hand is: What are the expected patterns and magnitudes of changes that we can anticipate, given the current state of knowledge of the Bay ecosystem and the construction project as described in this report? The challenge URS and its subcontractors have accepted is enormously complex. No group of scientists and engineers, regardless of expertise and funding level, could answer this difficult question with a high degree of certainty. Each step of the assessment described in this document contains inherent uncertainties, some of which are large. The task URS faced was to set the results of the studies in a context that explains the uncertainties clearly and to use all of the tools at its disposal to derive and validate its findings.

The Panel provided the following material to the Project Team in its comments from December 2002. The purpose of these more detailed commentaries on selected topics was to state issues the Panel believed were important as URS completed the studies, to provide guidance to URS on issues the Panel had raised during its review, and, in anticipation of this report, to provide a context for the public to use in evaluating the scientific and technical studies. Where the Panel suggested particular courses of action in these comments, URS did respond and conducted the analyses suggested and addressed the questions asked.

It is presented here both as information for readers interested in these topics and to illustrate some of the substance of interactions between the Panel and the Project Team.

A. Models and Model Use Strategies

The URS technical team has accepted a challenge of extreme complexity—to assess the full suite of potential responses of San Francisco Bay to a set of proposed runway construction alternatives at SFO and how those responses would be manifested in changes of the Bay's characteristic processes and phenomena, both during construction and following completion of the project. The challenge has two basic components:

- Assessment of responses expressed as changes in the transport patterns of water and sediment (including deposition/erosion); geochemical processes related to contaminants that could potentially impair San Francisco Bay's biological communities from phytoplankton to birds, mammals, and man.
- Compilation of a variety of lines of evidence to make a compelling case that these assessments are fundamentally correct.

The NOAA Science Panel has evaluated both components of the challenge. We have evaluated both the methods used to forecast impacts and the approaches used to assess the reliability of those forecasts. The assessment of project impacts relies heavily (and for some impacts, exclusively) on outputs of numerical simulation models. Simulation modeling not only is an appropriate approach for assessing potential impacts of this project, it is the most powerful approach for framing the bounds of probable impacts and for identifying areas of uncertainty that require further investigation. Most of the models URS used are state-of-the-art, and they can be used as components in the logical inference that is required to evaluate the probable impacts of this project on the processes and phenomena that characterize San Francisco Bay.

All models are simulations and have some scope or dynamic domain within which they can be expected to provide useful guidance. This guidance can be such information as demonstrating critical processes or important links among systems. Within the combined scope of the models used, the URS work has reinforced and supported intuitive understanding. The modeling generally has been consistent with the often-sparse direct observational data that are available.

In some cases, however, direct observational data are not available or are impossible to obtain. URS generally has responded with the development of additional lines of evidence for a number of the critical issues—but not all model outputs have been verified with alternative approaches.

The fact that the combined scope of the models used does not cover all of the potential areas of inquiry, however, should not come as a surprise. The present effort will not close the book on environmental studies of San Francisco Bay, but does make a significant contribution to our understanding of the system and how it might respond to a specific set of proposed perturbations.

B. Strengths and Limitations of Modeling

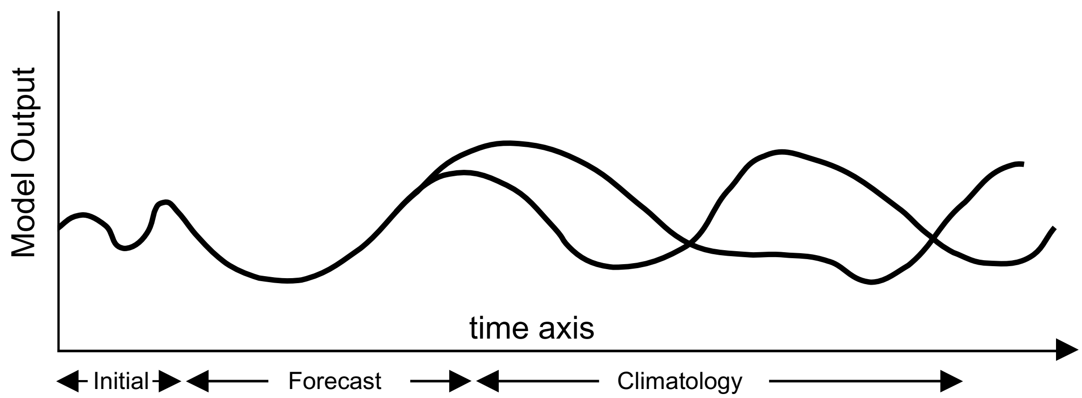
A model is a representation of reality that is designed to capture the defining qualities and/or distinguishing characteristics of the thing being modeled and to portray those characteristics clearly. This is true whether the model is a model ship or a 3-D numerical model of San Francisco Bay. Models are ways of dealing with complexity, scale, transitory conditions, and other factors.

There are three basic types of models:

- *Simulations of systems or parts of systems.* Mickey Mouse is a simulation of a mouse: he looks nothing like a mouse, but the simulated ears, nose, and tail allow us to recognize that he is a mouse.
- *Dynamic explorations* allow us to understand effects or potential effects of perturbations of systems. By varying initial conditions, dynamic explorations can be used to understand the range of possible outcomes for a given set of circumstances.
- *Reproductions* of essential physics and their interactions allow one to forecast physical conditions at some point in the future.

NOAA Weather Service activities offer a specific example of how useful information can be obtained from models. The Weather Service has many models, and huge experience in using them. The forecasts that NOAA issues are not model output, but rather a forecaster's digestion of many informational threads based on models, data, and experience.

The following figure gives a generalized example of model output. After a model is started there is an initialization period when it is "spinning up" or "ringing" because the interior is not in equilibrium with the imposed forcing. After that, there is a period when the model dynamically adjusts and is realistically tracking some dependent variable (temperature, relative humidity, etc.), which represents the "forecast" or deterministic region. For most dynamic systems, non-linear processes come into play and the resulting chaos behavior leads to bifurcation, extreme sensitivity to initial conditions and multiple solutions. At this point, the model may generate a realistic "synthetic" climatology, but it is no longer deterministic and the solution becomes a "for instance" of what could happen rather than an actual time-based prediction. Statistics on the distribution of solutions may be useful, but details are not. Again using a weather example, global climate change models predict higher mean temperatures and greater variance, but no particular daily values. There is information, but it is based on a different sort of analysis of model output than the familiar time dependent forecast. How the model results are used becomes critical. For someone planning a garden for five decades from now, the model won't provide information about the best day to plant, but does suggest that the gardener should be looking for varieties of tomatoes that can survive shorter, warmer growing seasons.



The hydrodynamics model of tidal currents, for example, is continually linked to the dominant oceanic tidal heights and the actual simulation time is just how long it takes those tidal waves to propagate through the Golden Gate and into the various arms of the Bay (and partially reflect back). The model is always being run in its comfortable "forecast" region. Not surprisingly, the model forecasts can be compared satisfactorily to observed tidal heights in the Bay. Obviously, the information from the model can be used directly.

Combining a suspended sediment modeling component with the hydrodynamics output adds a layer of complexity. The suspended sediments model is a parabolic formulation that uses the hydrodynamics model as independent input, and incorporates winds, fetch distances, existing substrate characterizations and so forth. Many of these components are non-linear; consequently there is no attempt to examine projected sedimentation as a forecast output. The results are presented only as statistics on the generated synthetic climatology. That is, mean deposition or erosion rates are projected over extended periods. Here the information use strategy is different from the previous case, but both are clear and appropriate.

Another layer of complexity is represented by what we think of as more loosely coupled chains of inference. The sediment modeling output changes suspended sediment values. Many of the toxins present are strongly bound to the sediments. Two information chains meet. Biological data are almost always presented as statistical information (or "bioclimatology" to borrow terminology from physical modeling). And questions about the extent to which the population statistics are parametrically dependent on the suspended sediment levels and their toxicity and how the conceptual model ties these information chains together become important.

C. Sedimentation

At any given time, sediment in an estuary is either suspended in the water column or resting on the bed. Construction activities and presence of the reconfigured runway would affect both compartments. Suspended-sediment concentration (SSC) may be increased in the vicinity of dredging operations, increased tidal currents, and more intense wind wave activity. SSC may be decreased where wind waves and tidal currents are reduced. Changes in SSC, tidal currents, and wind waves may determine whether the bed at any location is erosive or depositional, and may change the rate of erosion or deposition (geomorphic evolution).

A numerical model was developed to predict how the project could affect sedimentation. The model resolves changes in SSC on tidal time scales (hours and days) and was calibrated and verified with SSC data from cruises and serial observations at fixed stations. Simulated SSC compares well with measured SSC not used to calibrate the model, and thus the model is demonstrated to have the capability to predict SSC changes created by the project. Model results are extrapolated to the geomorphic time scale (decades) to predict geomorphic evolution and habitat change. In order to test whether the model can predict geomorphic evolution of the estuary, the Science Panel asked that model results be compared to historical geomorphic evolution. The model was used to hindcast geomorphic changes in South Bay from the 1950s to 1980s, which is a difficult verification of the model because the model was calibrated to SSC, not geomorphic evolution. Small errors in SSC and sediment transport accumulate to become large errors in geomorphic evolution. The results of this hindcast were poor when compared with observational bathymetric changes. This demonstrates that the model cannot be used to reliably predict geomorphic evolution.

The model's poor performance in predicting geomorphic evolution is not surprising and is not a reflection on the quality of the hydrodynamics and sedimentation modeling. It does, however, highlight the importance of pursuing multiple lines of inquiry to understand geomorphic change and other changes over periods of years to decades.

To reduce the uncertainty associated with predicting how the project will affect geomorphic (and therefore habitat) evolution of the Bay, other methods should be applied. Previous projects in the Bay have created areas of infill (runways and causeways) and borrow pits and should be used as case studies for evaluating the potential impacts of this project. The results of previous shoreline erosion and wetland accretion studies in South Bay should be considered. For example, have previous large borrow pits had a demonstrable effect on shoreline erosion or wetland accretion in South Bay? Historical sources of data such as bathymetric surveys conducted for charting purposes are a data source that would allow an analysis of change in the Bay over time. Similar projects in other estuaries also could be used as case studies for illustrative purposes.

The information needed to develop a sediment budget for South Bay has already been gathered and the impact of the project on the sediment budget can be predicted. Analytic and simple "back of the envelope" calculations may also be useful. Prediction of geomorphic evolution is difficult and will have a higher degree of uncertainty than prediction of SSC, but using several methods of inquiry may produce a weight-of-evidence indication of the expected impacts of the SFO project and reducing uncertainty.

D. Effects of Contaminants

Chemical toxicity is a function of molecular structure, biologically available concentration, exposure time, and the sensitivity of receptor organisms. Different organisms differ considerably in sensitivity and response to different chemicals. With such variability it is impossible to predict exactly the toxicological effects of the runway expansion where multiple toxicants would be present and biological resources potentially at risk. Thus, it becomes very important to build a case using multiple lines of evidence. This case building is equivalent to a medical doctor using outcomes of multiple tests to determine what, if anything, is wrong with a patient. The toxicological tools with which to make such a case for this project are currently available and have been used previously. It should be recognized that biological resources now in San Francisco Bay are constantly exposed to chemical stressors as well as physical and other stressors. The issue, then, is one of addressing the additive effects of the runway expansion.

Issues to consider and evaluate (which are part of a conceptual model of how the biological system reacts to contaminant inputs) ideally would include:

- *Quality of water column.* Runoff from the runways, atmospheric deposition of jet exhaust (with pyrenes and other PAHs), and construction-related resuspension of contaminated sediments can lead to increased concentrations of toxicants in the water column and on the sea surface micro-layer. Table 6.1-1 (Conceptual Model Linkages) states that no permanent effects related to water quality are expected. This conclusion must be defended and supported with suitable data and appropriate multiple lines of reasoning.

- *Quality of surficial sediments.* Sediments at the site are currently contaminated at moderate levels based on the limited set of site-specific analyses. These sediments are typical of those throughout much of the system. Concentrations of a number of contaminants already frequently exceed low-range guidelines and ambient thresholds and they are occasionally toxic in laboratory bioassays. Multiple lines of evidence are necessary to conclude convincingly that runway expansion will not increase these concentrations sufficiently to pose toxicological risks to local biological communities.

- *Structure and function of benthic communities.* Resident populations of benthic infauna at the site are typical of those found throughout much of the system (neither unusually luxuriant, nor depauperate). However, they represent important elements of the ecosystem and as prey items they represent a potential route of toxicant uptake and exposure for demersal fishes and other higher trophic level biota. Permanent and quantifiable losses of the benthos will occur as a result of burial under the runway footprint. It is highly likely that the local infauna will respond to changes in depth, sediment texture, organic carbon content, and other natural factors as well as the concentrations of toxicants. If the runway expansion affects these factors, the degree of change in the benthos attributable to these factors also must be estimated beyond the footprint of the runways themselves.

- *Health and abundance of demersal fishes.* Demersal fishes (sole, flounder, sand dabs) are intimately associated with the sediments and as a result, are vulnerable to changes in sediment quality. Toxicant-related effects on demersal fishes (starry flounder) have been demonstrated in San Francisco Bay in previous studies (Dr. Robert Spies, Lawrence Livermore National Laboratory). Indicators of reduced health include bioaccumulation, PAH metabolites in bile, presence of lesions, reduced fecundity and reproductive success, and irreparable DNA damage. The Army Corps of Engineers Waterways Experiment Station maintains a website (Environmental Residue Effects Database, ERED, available at http://www.wes.army.mil/el/ered/) which contains matching biological effects and tissue residue concentrations to aid in evaluating risks of contaminant bioaccumulation. Sediment-bound PAHs, PCBs, mercury, etc., are among the causative agents for many of these adverse effects. PAHs may reach the Bay from the Airport runways. Multiple lines of evidence are necessary to conclude convincingly that runway expansion will not adversely alter existing levels of toxicants in the Bay to the point of increasing existing levels of adverse effects among local demersal fishes.

- *Health of migratory salmonids*. It has been demonstrated in Puget Sound that juvenile salmon migrating to sea through urban bays are exposed to and accumulate toxic chemicals in their tissues during their short residence times (one to two months) in these bays. These chemical concentrations are sufficient to decrease their health as juveniles and reproductive success as adults. Because migratory salmon will pass near the runways, they may become exposed to elevated levels of toxicants both during construction and operations phases. Therefore, it is important to demonstrate that neither runway construction nor operations would adversely affect these species, some of which are threatened or endangered.

- *Health of marine birds and mammals.* Decreased eggshell thickness, decreased egg production, decreased hatching and fledging success and other related problems can result from exposure of marine birds to toxic chemicals. Decreased reproduction (e.g., aborted and stillborn fetuses) has been reported in seals exposed to PCBs and other toxicants in U.S. and European systems. Marine birds and mammals currently living in the Bay are exposed to toxicants and other stressors. Tools for conducting ecological risk assessments in which sediment-bound chemical concentrations are equated to concentrations that would be expected to bioaccumulate in fishes, birds, and mammals are available through the U.S. EPA and the Fish and Wildlife Service. Bioaccumulative effects should be addressed in the summary Table 6.1-1 (Conceptual Model Linkages).

- *Health of human consumers of local fish*. Invariably, the question will come up as to whether expansion of runways farther into the Bay will adversely affect the quality of fish that people catch there and eat. The current risks of increased health effects, including risks of elevated incidences neurological damage and cancer, can be calculated using existing fish tissue data from the Bay and health advisories on mercury and organic contaminants in some fish. The state of California has calculated such risks for many California bays, including San Francisco Bay, San Diego Bay, Santa Monica Bay, and Monterey Bay. Tools for risk calculations have been available for many years from U.S. EPA. Risk estimates among consumers of Bay fish should be estimated based on expected increased exposure to contaminates from runway construction and compared to pre-construction risks.

For each issue, there should be a description of the potential route of exposure (i.e., water, sediment, food ingestion), the existing sediment and water quality conditions, the predicted conditions, the kinds of adverse effects that could be expected as a result of the exposure, followed by a logical basis for either dismissing the potential effects as insignificant or an estimate of the degree and spatial scales of the projected effects. The toxicity of chemicals is a function of their structures, concentrations, and exposure times; the document should address all of these factors with each line of evidence. A very effective way to characterize the contribution of the expanded runways to total toxicant loads into the Bay would be via calculations of mass balance or loadings. The percentage contribution from construction and operation of the Airport runways to total inputs of toxicants to the Bay could be calculated to provide perspective. The mass balance, then, should be followed by descriptions of the chemical and physical fates of these chemicals. If an evaluation suggests that conditions in the Bay could be toxic, estimates of spatial scales and duration of losses must be placed in the context of what is happening in the rest of the Bay. It is important that a comprehensive evaluation include both the construction and operational phases of the project because they are inextricably linked.

E. *Uncertainties and Constraints*

Any attempt to model natural systems confronts both uncertainties and constraints and should explicitly consider both. Uncertainties can be in the reliability and completeness of the data used or in the ability of the algorithms to capture a process or a part of a process accurately. Constraints are the limits of the ability to the models used to produce useful results at various scales of time and space. The advantage of applying multiple assessment approaches becomes apparent when we consider these limitations inherent in all models. The computer-based numerical models used in this assessment are state-of-the-science, and simulations performed by URS were done in a systematic and logical manner to produce one type of predicted system response. The quality of any computer-based simulation is highly sensitive to the degree to which dynamic processes can be described with governing equations and the fidelity with which the mathematical models encapsulate all the key processes. This leads to varying reliability (uncertainty) of model outputs. For instance model-predicted changes in tidal currents (for which the governing equations are complete and well understood) have greater reliability than predicted changes in water quality. The scientific community has less faith in model-based predictions of water-quality change because chemical dynamics are more complex, less well understood and therefore more difficult to capture with models. Uncertainty of predictions becomes especially high when all the key processes of change are not included in the models.

The water-quality model MIKE 21, used here to predict changes in the concentrations of potentially toxic metals (copper, nickel), illustrates the problems of uncertainty and constraints. This model does not include the biological processes of uptake and assimilation by phytoplankton, which are known to be important controls on the biogeochemistry of some metals. We are fortunate in the Bay area to have one of the world's experts on the cycling and effects of trace-metals in estuarine ecosystems, Dr. Samuel Luoma. In one of his studies of trace-metal cycling in South San Francisco Bay, Dr. Luoma and his colleagues demonstrated that dissolved reactive metal concentrations become depleted during periods of rapid phytoplankton production and population growth. In this study, Dr. Luoma and colleagues concluded that about half the annual point source loading of reactive metals in South San Francisco Bay is processed by the phytoplankton—i.e., assimilated and converted from dissolved to particulate form that can be transferred to consumers and incorporated into the food web. This process is not included in the MIKE 21 model, so it is reasonable to question the reliability of predicted changes in metal concentrations. We use this example to illustrate the complexity of the problem, the importance of understanding sources of error in model-based predictions, and the value of complementing model-based predictions with other approaches.

In this section of our comments, we have identified some of the problems and goals associated with trying to use a modeling framework to couple various levels of inference. It is generally the case that as physical water-movement is linked to distribution or transport processes, which in turn are linked to biological processes, the resolving power of the inference decreases.

Many aspects of the report suggest that the proposed runway development will not result in any "significant" change to the San Francisco Bay system. To establish this "null hypothesis" based on model results places some special burdens on the model (both conceptual and numerical) development teams. At a minimum, an explicit analysis of uncertainty and constraints of the models should be included. This requires some documentation of specific steps, some of which already are present as threads within the existing report:

- The forecast period of the models that are used needs to be defined, including the parameter ranges in which the models are deterministic, and possible extensions of the parameter domain where they are not deterministic, but can provide useful statistical information concerning aspects of the "computational climatology." For example, an extended run of an atmospherically and tidal-component driven circulation model will certainly provide means and standard deviations of the currents.

- Since the models' dependent variables (deterministic or statistical) will serve as independent variables in the following level of inference, it is necessary to know their expected accuracy. For example, how well does the model predict the 10% strongest currents that would dominate sediment erosion processes? This is generally a hard question for modelers to answer, particularly if grid smoothing has been used and channels have been artificially widened. How do you know if important jets or filaments in the currents have been lost, thus degrading the high-speed spatial or temporal statistics? In many cases the only way to get convincing answers is to conduct "numerical experiments" to show model sensitivity to parametric or domain specifications. (We note that this sort of numerical exploration was done with respect to 2-D vs. 3-D formulations of the hydrodynamics.)

- Each higher level of inference must rest on the available information from the predictions in the previous step. To tie the entire conceptual framework together it must be clearly documented that the available information provides appropriate components of the dependent variable set needed to continue. It is often the case that previous model results will also have to be augmented with other domain data that may have been derived from observations, or alternate analysis or inference schemes. How each level of inference uses the deterministic, statistical, or external data is an essential component of the overall conceptual modeling effort.

- A step that is often ignored by modeling teams is considering whether the expected accuracy in the output from a previous stage in the logical chain of inference is sufficient to instigate changes that are resolvable at the next level in model. In particular, the modeling team must be able to document the statement "if there were an expected change, we would have seen it." This is potentially a difficult step in the modeling presentation and may require the backup of numerical exploration and sensitivity analysis.

F. The Value of Multiple Assessment Approaches

The most reliable assessments of ecosystem response to change are built from the application and integration of multiple assessment approaches. When outcomes of independent approaches converge, our confidence in the reliability of assessments grows. When only one assessment approach is applied, it is difficult to gauge our confidence in predictions. URS and its associates have placed considerable faith in the application of only one approach for forecasting responses of the Bay system. A central issue for the NOAA Science Panel is reliability of predictions based on modeling alone, in the absence of validation or verification from other independent approaches. The specific predictions from model simulations and (especially) subjective judgments based on model predictions, would be more certain if they were confirmed by carefully documented observations of changes measured in other coastal water bodies subjected to physical disturbances of comparable magnitude to the SFO runway reconfiguration.

G. Learning From Other Large Projects in the Coastal Zone

The specific forecasts from model simulations and, especially, the assessments made where modeling was less appropriate and data sparse would be more certain and convey a greater level of confidence if, for example, they were supported by carefully documented observations of changes measured in other coastal water bodies subjected to physical disturbances comparable in magnitude to that of the SFO runway reconfiguration. That is, our confidence in the predictions about the proposed project would be greater if they were supported by relevant findings from a systematic review of the measured biological responses observed in other aquatic ecosystems subjected to similar large-scale within-estuary construction projects and sustained physical disturbances.

Examples of other large projects in coastal areas that could be appropriate for analysis include: Hong Kong's Chep Lap Kok International Airport, expansion of the Honolulu International Airport, Osaka's Kansai International Airport, Sydney Airport's 1988–1995 runway expansion project, and the Inchon, Korea industrial park project. The large projects need not be airports.

The Panel recognizes that monitoring programs to assess the effects of projects such as these are rarely implemented. This unfortunate fact should give more impetus for establishing appropriate long-term monitoring to assess the effects of the SFO runway project if it is built.

Appendix II

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April 2003
Panel comments and Project Team responses for the Panel II meeting held in April 2003

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Commerce Press Release
Press release issued by the Department of Commerce/NOAA/NOS

Public Forum Agenda
Agenda provided to Public Forum attendees

Public Forum Transcript
Verbatim transcript of the Public Forum

Public Forum Panel II Q and As
A few questions and answers on the Panel provided to Forum attendees

URS Presentation

URS Presentation
The overview presentation URS managers and scientists gave at the Public Forum

URS Text and Images
Images from the URS presentation merged with (unedited) text from the Public Forum transcript

Public Forum News Clips
A compilation of news clips of newspaper coverage of the Forum

V Final Report

Independent Peer Review Panel Final Report
The Panel II report in digital form

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